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Popular Science Talks

SEASON OF 1930

Presented by Members of the Faculty of the

Philadelphia College of Pharmacy and Science

and Published Under the Auspices of the

American Journal of Pharmacy

(SINCE 1825 A RECORD OF THE PROGRESS OF PHARMACY AND THE ALLIED SCIENCES)

With the Aid of a Fund Established in Memory of
Mr. Thomas D. Simpson
of Philadelphia

Volume No. VIII

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Edited by IVOR GRIFFITH

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FOREWORD

FOLLOWING the second year of the presentation of these Popular Science Lectures by the Faculty of the Philadelphia College of Pharmacy and Science a demand arose for the lectures in book form, in spite of the fact that most of the lectures had appeared in the AMERICAN JOURNAL OF PHARMACY following their presentation.

This demand has been supplied for the past seven years and the following paper-bound volumes with their lecture subjects are available at a cost of $1.00 per individual volume. The College distributes these lecture volumes at cost, as part of the educational program. They have found a ready use in the libraries of teachers, students and persons interested in the scientific phases of everyday life. As an abundant reservoir of interesting information they have proven extremely useful to those called upon to make luncheon and club talks.

They are appropriate, inexpensive gifts (holiday, birthday or just plain gifts) for students, pharmacists, physicians, school and fraternity libraries.

Volume I includes 12 lectures as follows:

"Chemistry as an Aid in the Detection of Crime," "Corn and Its Products," "The Story of Glass," "Bacterial Preparations," "Another Drop of Blood," "The Romance of Spices," "Catalysis and Catalysts," "The Aluminum Age," "Animal Eating Plants," "Explosives and Explosions," "The Making of Medicines," "Iron and Iron Alloys."

Volume II includes 11 lectures as follows:

"Invisible Light," "The Story of Rubber," "Chemistry in and About the Home," Idiosyncrasies, or the Story of a Sneeze," "What is Chocolate?" "Sugar as a Medicine Food and Poison," "Social Insects," "The Romance of Drugs," "Something About Gases," "Household Insect Pests," "Drugs of the North American Indians."

Volume III includes 13 lectures as follows:

"Arctic and Tropical Pennsylvania," "The Romance of Chemistry," "Chemistry and Color," "The Mineral and Vegetable Resources of the Sea," "Chemistry in and About the Home," "The Ups and Downs of Nitrogen," "Animal Aviators," "Practical Disinfection," "Why Soap?," "What Shall I Eat?," Bridge Construction," "Chalk and Its Chemical Relatives," "Control of Growth in Plants and Animals.'

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Volume IV includes 12 lectures as follows:

"The Romance of Medicine," "More About Color and Colors," "Coal and Coal Mining," "Environment—The Big Factor in Health and Disease," "Imitation of Life," "The Sign of the Skull and Cross Bones," "Delectable Confections," "The Flight of a Ball Through the Air," "The Diamond and Its Colored Brethren," "What Shall I Drink?," "The Salt of the Earth," "Abnormal Plant Growths."

Volume V includes 11 lectures as follows:

"Paper," "The Romance of the Occult," "Epochs and Epoch Makers of Medicine," "The Story of Burnt Clay," "Hormones, Vital Substances in Life," "Epidemics, Man's Most Deadly Enemy," "My Lady Nicotine," "Sand, From Mountain to Seashore," "What Shall I Wear?," "Why the Weather?," "Mosses and Their Message."

Volume VI includes 13 lectures as follows:

"The Rare Elements," "Flame," "Ice," "Building Stones, Natural and Artificial," "Where and What Are the Stars?," "The Realm of the X-Ray," "Some Questions Relating to Life," "The Romance of Cookery," "The Preservation of Food," "European Flowers as an Important Factor in Culture and Commerce," "Sumach and Poison Ivy," "The Heart," "Animals That Live on Man."

Volume VII is only available in a clothbound edition, priced at $1.50.

Volume VII includes 13 lectures as follows:

"The Modern Sun Cult," "The Romance of Beverages," "Soil and Sod," "Time—What Keeps It," "How Much Do You Weigh," "The Cosmetic Urge," "Snakes and Snake Protection," "Heart Beat and Blood Flow," "The Carbon Oxide Brothers Mon and Di," "The History and Mystery of Pyrotechny," "Little Drops of Water," "Evolution of the Motion Picture," "Iodized Salt—A Food or a Drug."

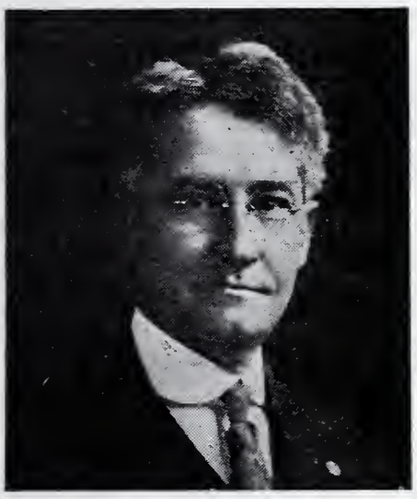
The present volume (Volume VIII) is offered, paper bound, at $1.00 the copy.

Note.—The volumes of Popular Science Lectures are now published with the aid of a fund established for this purpose in memory of Mr. Thomas D. Simpson, of Philadelphia.

THE CHEMIST AS A DETECTIVE

By Charles H. LaWall, Ph. M., Sc. D.

THE TITLE OF THIS LECTURE is one which may attract some and repel others. It all depends upon the viewpoint and upon the interpretation of the two principal words—"chemist" and "detective." There was a time when the word "chemist" meant a long-whiskered individual who led a hermit-like existence and whose search for mysterious kinds of knowledge was conducted more or less secretly and with the assistance of a queer looking lot of apparatus. The alchemist, as the practitioner of the art was called, was usually a seeker after the unknowable —the philosopher's stone or the elixir of life, for example.



Charles H. LaWall, Ph. D., Sc.D.

The detective of the older type of fiction was a "gent" with false whiskers and rubber-soled shoes, who carried a gun and who was always ready to flash an official badge at a moment's notice by nonchalantly throwing back his coat lapel.

Nowadays there are as many kinds of chemists as there are varieties of automobiles, and while every chemist is a detector, or one who brings facts to light, there is only a limited number of members of the profession who are qualified by training and experience to cope with the many phases of the science which have to do with the detection and punishment of crime. It is the latter group with which we are particularly concerned upon this occasion—the chemists who are called upon to support some phase of the law, either criminal or statute, and I am sure of interesting at least that part of my audience who are members of the anomalous organization called "The Crime Club," in which membership does not necessarily presuppose criminality on the part of the applicant.

The modern detective novel is a fascinating form of literature to a very large proportion of readers of current fiction, and many authors in this field have availed themselves of the possibilities in modern chemistry to make their works more attractive and to pro-

vide new thrills. Sherlock Holmes has become a household word, although the original Sherlock, while versed in chemistry, did not often employ it as an important factor in the solution of the mystery at hand. Craig Kennedy is more modern and more scientific in his methods, although his greatest reliance is upon physical apparatus for recording psychological impressions. The creator of Fu Manchu, and the equally versatile and perennially fruitful Edgar Wallace are fully conversant with chemical science and its possibilities in fiction, but no author as yet has more than touched the fringe of the subject; in fact, I venture to say that the official reports of A. Lucas, O. B. E., F. I. C., Director of the British Governmental Laboratory and Assay Office at Cairo, contain more potential plots and more fascinating stories of crime detection by chemical and related methods, than have ever been used by all of the writers of detective fiction from the time of Dioscorides to the present.

"ITALIANATED"

I mention Dioscorides, for while he was not a writer of best sellers of his time, he certainly was the one who first classified poisons and described their effects, though it was many centuries before the analytical chemist appeared upon the scene with his methods for detection and estimation of substances administered for the purpose of destroying human life. And poisons have played an important part in history from the time of Tiglath Pileser to the present. At one period in the history of Italy the practice of poisoning for revenge, profit, or for almost any other reason, may be said to have been pandemic, and the names of the Borgias, the Medicis, and Madame Toffana will be forever associated with toxicology. One of the famous poisons of that time (probably a preparation of arsenic) was called "Powder of the Succession," because it was so frequently used by younger sons in speeding up the acquisition of the title. To be "Italianated" meant to be the victim of poison secretly administered.

Thanks to the researches of modern chemistry, beginning with Orfila, more than a century ago, the proof of the presence of poison is so certain in our time that poisoning is a rare charge or count in a modern bill of indictment for murder, and with some poisons the basic elemental substance is so indestructible that chemical evidence of the presence of poisoning could be obtained even after the lapse of centuries.

POISONS OF HISTORY

I doubt not that if the tomb of Alexander the Great were to be discovered and the remains submitted to a chemist for examination, it could be determined with certainty whether any of the mineral poisons commonly used at that time, such as arsenic, lead, or mercury, were present, for it will be remembered that Alexander's last illness, which some authorities believe was due to the administration of poison, was of several weeks' duration, which would indicate the use of a mineral poison rather than one of the poisons producing a rapid effect, such as was used with such success by Locusta in the poisoning of Britannicus. In this latter case the poison was probably one of the forms or combinations of prussic acid, which had been known and used from the time of the Egyptians, who referred to its use in the enigmatic phrase "the penalty of the peach," thus indicating a knowledge of the fact that peach kernels contain prussic (hydrocyanic) acid, and also, inferentially, that they were able to prepare this poison in a concentrated form from the source named.

While I do not purpose devoting more than a small portion of the allotted time to the subject of toxicology, it may be appropriate to mention that a Greek writer named Nikander, of the third century B. C., wrote a comprehensive work on poisons and referred to certain complex preparations of drugs as specific antidotes; those which were to combat the effects of the bites of venomous animals or insects were called "alexiterics," while those which were effective against drugs administered internally were called "alexipharmics." The name "theriac," derived from the first of these two words came to be employed for many centuries to designate remedies which were supposedly effective against all kinds of poisons.

Poisons of vegetable origin, such as the toxic plant principles, strychnine and morphine, etc., are not as resistant to putrefactive changes as are the mineral poisons, but their detection and estimation within a short time after administration is usually certain, and taking into account the symptoms preceding death and the observations and opinions based upon a post mortem conducted by a properly qualified individual, poisoning by such substances is usually promptly detected and punished if the investigation is in the hands of competent authorities and is instituted promptly.

It is in connection with such poisons as venoms, toxins, ptomaines and disease-producing bacteria that the chemist is still unable to proceed with certainty, but such methods of poisoning are rare and

there are other sciences than chemistry that are helpful in bringing about detection and conviction.

Few analytical chemists are available for or care for such toxicological work as is necessary in connection with poisoning cases. The materials are not pleasant to work with, the chemist often being required to be present when the post mortem is conducted, and the responsibilities are very great indeed. Certain phases of this work, common to all chemical work which is to play a part in court procedure, will be discussed later in detail.

POISON PLOTS

Only one who has had experience as a public analyst can have any conception of the number of individuals in a community who have an idea that they are the victims of poisoning plots. The great majority of these, fortunately, are imaginary cases, but every once in a while the analyst is surprised and astonished at the boldness with which such crimes are attempted. I remember one case in which a sample of a well known proprietary infant food reached me from a nearby medical school to which the sample had been sent by an alumnus of that school who was a practicing physician in western Pennsylvania. The facts accompanying the sample were meagre, but the first preliminary test revealed arsenic, and further investigation showed the presence of a dangerous amount of white oxide of arsenic, commonly available as "Rough on Rats."

A long-distance telephone call acquainted the physician with the facts so that remedial measures might be promptly instituted, and it was then learned that the package had been returned to the doctor's office by the young mother of an illegitimate child, the father of whom had presented her with the package (and had probably added the poison). The young mother, not associating the death of the child with the food, returned it to the physician's office together with some unused medicine, and the physician's wife, seeing this package of baby food on her husband's desk, and noting that very little had been used out of it, took it for her own child, who promptly developed diarrhœa, which is one of the early symptoms of arsenical poisoning.

It is almost unbelievable, yet true, that the physician who sent in the sample which had poisoned his child, refused to pay any fee, nor even the charges for the long-distance telephone call, because, as he said, he had sent it to his own college where they should have

done it for nothing, and had not expected them to incur any expense without notifying him beforehand.

Another case of attempted murder was revealed by the examination of some biscuits baked by a young bride for her elderly spouse. The biscuits were brought in by the physician who was attending the elderly man, as he suspected that something was wrong with his patient's food and took a chance on the biscuits. Upon examination they were found to contain over 5 per cent. of white lead which had been mixed with the flour. A very clever attempt, because the symptoms of lead poisoning are not always the same and poison is not always suspected in such cases by the attending physician.

A sample of tea was once handed to a food inspector by a complainant who said that her husband had been ill ever since she had used tea from that package for his meals. As she did not drink tea she picked upon that article of the diet of which only he partook. This was a case of added arsenic, like the baby food case previously related.

Samples of candy which has been maliciously poisoned are occasionally encountered, but the great majority of suspected cases result negatively upon examination of the sample. One positive case, just recently investigated, concerned a single stick of chewing gum handed to a young lady by her boy friend. She suspected it for some reason which she would not disclose. An examination of the sample showed that the white powdered sugar which ordinarily is used on the outside of chewing gum sticks had been replaced by white arsenic.

In another instance bichloride of mercury was found mixed with the sugar in a boarding house sugar bowl, and in still another, calomel was found mixed with the sugar in the sugar bowl on the private table of the landlady herself.

"TOXICOMANIACS"

All of these cases are unfinished, so far as the analyst is concerned, for no criminal charges resulted in any of them and no further facts were communicated to the analyst. There are persons in every community who might with propriety be called "toxicomaniacs," not because they are in the habit of giving poisons to others, but because they are constantly laboring under the mistaken impression that they are being poisoned. The few cases cited above are but a small proportion of those investigated, but in every sample submitted a thorough and careful examination must be made to avoid overlooking a case which might result in tragedy.

A "NOVEL" NOVEL

In closing this portion of the lecture I should like to remind my hearers that the novel "Stringtown on the Pike," written just thirty years ago by that famous pharmacist and internationally famous scientist, John Uri Lloyd, has for its dramatic climax a scene in which the chemical testimony of an acknowledged authority who had apparently proved the presence of strychnine in the stomach of the victim by a test which had hitherto been considered infallible, was nullified by a self-constituted investigator in the person of a student of chemistry who had faith in the innocence of the accused, and who by a clever series of experiments and deductions from the facts brought out by the defense in the trial, was able to prove that this hitherto infallible test for strychnine was fallacious and that the same reaction could be produced by other common drugs which had been admittedly used for medicinal purposes by the deceased. The story was not only a good one but the statements made in the dramatic climax, when the case was reopened for the admission of new testimony, are all scientifically correct. This is the first time in the history of chemistry that a novel was used as the medium for the original publication of an important scientific discovery. The book created a furore among toxicological chemists at the time of its publication in 1900, but not only were the statements verifiable, but the result has been to discredit what are called color reactions for the identification of alkaloids, unless supported by other chemical reactions.

Many famous criminal trials have been conducted in which the testimony of the chemist has played an important part; among those which attained international prominence in their time were the Maybrick case and the Carlyle Harris case. In the former it was arsenic that was used as the poison, while in the Harris case it was morphine, a capsule containing a lethal dose of this poison having been substituted for a single capsule of the same size and appearance in a dozen capsules containing a harmless headache remedy, the capsules having been filled on prescription. This was as difficult a case as can well be imagined, but Carlyle Harris was convicted.

Next in importance to toxicological cases or those involving poison, are those in which the recognition and identification of blood stains are necessary. The details of such tests are complex and not of popular interest, but I may say in passing that blood stains can not only be identified as such after the lapse of many years, but in addition to a number of general chemical tests there are now biological

tests which are specific for the identification of human blood as contrasted with the blood of other animals.

So many possible subjects of interest and importance could be mentioned that it is difficult to decide what phase of the work to take up next. Among these is the subject of explosives—their composition and their effects. A knowledge of this field figures in bombings and also in crimes in which firearms are concerned, where the composition of the projectile and markings on its surface received in its passage through the rifled barrel of the weapon and its contact with the object struck often lead to conviction.

The perfection of the recording of finger prints for purposes of study and classification is largely dependent upon chemical research, both in connection with the powder which is used to make visible the impression and the subsequent photography of the print, for it will be remembered that photography is primarily based upon chemical reactions. In this connection I had a very amusing experience while testifying in a civil case involving the value of phenol which had become slightly discolored while in storage. The judge (now deceased) who was sitting at this particular time was one of Philadelphia's most brilliant jurists, who frequently took the cross-examination out of the hands of counsel and conducted the case to his own liking.

HIS HONOR SEES THE LIGHT

After having testified to the assay strength of the phenol, which was well over 98 per cent. in spite of its dark color, I was asked by one of the counsels in the case what was the cause of the red color. I replied that so far as actual scientific knowledge was concerned the cause was a mystery, and I then enumerated a few of the alleged causes such as the presence of organic matter, the presence of iron, the action of light. At this point I was interrupted by the judge, who shouted at me in a very irascible manner, "Do you mean to stand there in the witness box and tell this court that light possesses the power to produce chemical changes?" I very modestly and quietly said, "Your Honor, the whole science of photography is based upon the chemical action of light." His Honor took very little active part in the rest of the conduct of the case so far as chemical or physical technicalities were concerned.

Both incendiary fires and fires resulting from spontaneous combustion present problems which may frequently be solved by the aid

of chemistry, for all combustion is a chemical reaction and certain substances often used by those who commit arson are usually detectable by chemical tests, unless the building or room is entirely destroyed.

GROUND GLASS HYSTERIA

In going over this miscellaneous list I am reminded by the fact that in the early days of the war when suspicion was rampant in connection with the alleged poisoning of foods, many glasses of perfectly good grape jelly were sent in to be examined for the presence of ground glass. The complainant would triumphantly point out the particles of glass (?) which were visible when the container of jelly was held before a strong light, and no amount of explanation would suffice at times until the chemist would carefully separate some of the particles in the presence of the complainant and show by a very simple demonstration with hot water and a test tube, that the so-called glass was soluble, which real glass of course is not, and that the substance under suspicion was really cream of tartar, which frequently separates out in a glass of grape jelly in the form of small transparent, sharp crystals.

One large manufacturer of breakfast cocoa during this same hysterical period came in to the laboratory with several samples of his product which were apparently normal in appearance and in flavor, but which upon cooking made a dark beverage of repelling appearance. Sabotage or tampering with the product by an alien employee was the thought in the mind of the manufacturer. An analysis of the cocoa showed the proximate constituents to be normal except for the fact that the color of the ash obtained on ignition indicated the presence of an abnormal amount of iron as indicated by the color of the ash. This in itself was not much to go on, but a lucky "hunch" led to the passing of a magnet through some of the original powder, to find upon its withdrawal that it had adhering to it innumerable microscopic particles of metallic iron. What was the source of this iron? A nail or a number of nails had found their way into that particular lot of cocoa beans, and when they entered the mill the iron was pulverized and the particles disseminated throughout the lot of powdered cocoa. The installation of a set of magnets in the feed hopper of the mill to attract and remove iron nails and other iron particles not only removed the difficulty, but the daily catch of nails and bits of iron convinced that particular manager not only

that his suspicions concerning sabotage had been unfounded, but that certain occasional defects in the uniformity of his product had been due to this same cause, which might never have been discovered had it not been for the fortunate (in this case) contamination with an unusually large proportion of iron.

CANDY ANALYZED

I had a very amusing yet costly experience some years ago when a candy manufacturer sent me a large sample of candy which had been made in a steam kettle near which an electric light bulb had burst and in which he feared some particles of glass might have found their way. The whole five-pound sample of the candy (it was a pure sugar candy) was dissolved in a sufficient quantity of water and the entire solution was filtered so as to catch any particles of glass that might be present. I carefully examined the residue on the filter for glass, but found none. I did find, however, the following list of foreign particles identifiable by microscopic examination: Fragments of wool, cotton and linen fibres, two varieties of wood fibres, cornstarch, yeast cells, several fragments of cigarette tobacco, fragments of wings and legs of insects, fragments of human hair, and of several kinds of paper.

In writing my report, besides stating that no glass fragments were present, I was tactless enough to give the list of things that I had found and to suggest that the factory had better be kept a little cleaner or the pans protected from dust, for of such miscellaneous character are dust particles composed as found on exposed articles or surfaces. I lost the client, who had frequently called upon me for analytical services. He didn't like my report, even though it was favorable as far as his original inquiry was concerned. After several years' absence, however, he returned and has since then seemed satisfied with the reports, but he has never again sent in any large samples to be examined for glass.

A POUND OF RAISINS, ETC.

When we were fighting for legislation some years ago to compel the covering of foods and beverages that are exposed to street dust, I had a prize sample of a pound of table raisins that were purchased from a street stand, and I still remember the effect that this report had upon a legislative committee before whom I had been called. The raisins were fuzzy with street dust. Besides the raisins I found all of the following:

Prunes, very dirty.
Beans.
Rice grains.
Dirt so thick on upper surface that the raisins looked fuzzy; numerous hairs visible.
Microscopic examination showed the following:
Hairs, human and animal.
Fragments of animal and vegetable fibres, cotton, wool, etc., dyed green, blue, yellow, brown, pink and gray.
Partly disintegrated bast fibres similar to those from straw, probably from manure.
Partly disintegrated bran fragments, probably from manure.
Sand.
Cornstarch, rice and wheat fragments.
Spores of yeasts and molds.
Pine wood fragments.
Fragments of three other unidentifiable woods.
Unidentifiable vegetable tissue containing spiral ducts.
Tobacco leaf fragments, probably from cigar butts.
Fragment of yellow stained cigarette paper.
Fragment of charred cigarette paper.
Fragment of cigarette tobacco.
Fragments of wings and legs of insects.

Another of the war time activities of the detective chemist was in connection of the enforcement of the regulations of the United States Food Administration when the nation was trying to conserve wheat in the effort to help feed the allies. These regulations were prohibitive as regards the use of unmixed wheat flour in bakery products. In fact, for this particular emergency our food laws relating to such products were literally turned upside down, and practices which were then made mandatory, were before and have been since that period, punishable under the food adulteration laws.

BOOTLEG BREAD

It was amusing to see how many bakers in Philadelphia refused to adulterate their products, their resistance not being based at all upon moral grounds, but upon the desire to serve their customers with the pure wheat products to which they had become accustomed, for as a matter of fact, the public did not like the foods made with the mixed flours and there was much

clandestine making and serving of pure wheat articles, "bootlegging bread," as we might appropriately describe it.

Now, to the food chemist the use of the microscope is a part of the daily routine, for microchemical tests play an important part in many of his investigations. Starches from different grains and cereals are markedly different in appearance under the microscope, and the accidental presence of other distinctive tissues makes it possible to detect with certainty the admixture of one flour with another, and a trained microscopist can determine the proportions of different ingredients with a fair degree of accuracy. The bakers who attempted to evade the regulations did so clumsily and were almost invariably detected and penalized.

One of the clever points in the handling of these cases was the fact that after a hearing had been held in the regulation legal manner, at which one of the food officials acted as judge and the defendant was permitted to have counsel and call witnesses, if the decision was "guilty" (and 90 per cent. of the defendants plead guilty after the first week's hearings), a fine was imposed in proportion to the size of the batch involved and whether it was a first, second or third offense, the fines were made payable to the American Red Cross, and the treasury of that worthy organization was augmented by many thousands of dollars in Philadelphia alone during the last year of the war.

THE FOOD CHEMIST

Now in these cases the story might have been different had a trained chemist supervised the mixing. In fact, there were formerly many branches of the food industry when the only use the establishment had for a chemist was to aid in systematically and intentionally violating the law, and for some years it seemed as if the violation advisory chemists were a few laps ahead of the law-enforcing chemists, but such is no longer the case.

This brings us naturally to the role of the chemist in detecting violations of the food adulteration laws, for such laws would be unenforceable were it not for the services of chemists who are experienced in that field. The responsibilities of the chemist in this connection are two fold: first, in the analysis of many samples of normal food products and establishing of standards of purity; second, in the devising of methods of detecting adulteration. In some instances the method of proving the presence of an adulterant is simple and positive; in other cases it is extremely complex and difficult.

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For example, as small a quantity as one teaspoonful of formaldehyde in 100 gallons of milk may be detected with certainty, although this amount is too small to be effective as a preservative,* while a modern, up-to-date complete report of the analysis of so simple a substance as cider vinegar is almost as complicated as an income tax report, and requires a gallon of vinegar and about two days' time to complete.

Thanks to the united and sincere efforts of national and state food law enforcement officials, aided by experienced chemists and inspired by the stimulating example and leadership of Dr. Harvey W. Wiley, practically all of the flagrant and harmful forms of adulteration formerly encountered have entirely disappeared. This does not mean that the battle is over. The general statement is intended to apply particularly to nationally distributed products or products entering interstate commerce where both state and federal authorities can join hands in the work of suppression. In some lines there is nearly as much adulteration as was formerly the case, but it is all of local origin and can be combated only by state and local authorities.

Some of the forms of adulteration in which the chemist's services are important and indispensable are as follows:

MILK ADULTERATION

Milk and cream were frequently found to be not only watered and colored, but were found to be preserved with formaldehyde or borax. The preservatives were used to save the cost of ice. In fact, formaldehyde solution was supplied to milk dealers at a fancy price under the suggestive name of "Iceline." In consequence of the rigid and continuous enforcement of federal, state and local laws affecting milk and cream, there are a few instances of recent years where milk or cream has been found to be tampered with. Butter, however, is still frequently found to be grossly adulterated with water. The legal limit of water is 16 per cent. Butter made by reliable creameries usually contains from 10 per cent. to 14 per cent. of water, and butter churned under normal conditions always falls within this range. A butter maker who knows the trick of incorporating excessive amounts of water in the butter can raise the water content up to 30 per cent., without materially changing the appearance or consistence of the butter, and we have had samples in the Philadelphia market containing

*This test requires but a teaspoonful of milk and a few minutes' time to perform.

as high as 38 per cent. of water—a tidy profit for the creamery that can get away with it. There once was a time when oleomargarine was largely sold for butter. Such substitution is now exceedingly rare, as oleomargarine has found its proper place as a butter substitute, openly sold as such.

There are very many comprehensive and detailed laws affecting beverages of all kinds. As an example of how well these laws cover the subject I can cite a case in which a sample of lemonade was purchased from a street vendor. Taking into account the conditions under which this lemonade was dispensed, part of which are under the jurisdiction of the inspector and with which the chemist has nothing to do, this sample was found to be illegal on five counts, which were as follows:

ALL FOR FIVE CENTS

1. It was sold from an uncovered container.
2. It contained ice, floating in the beverage itself instead of surrounding the container.
3. It showed a deficiency of lemon juice.
4. It contained saccharin instead of sugar.
5. It contained a poisonous amount of zinc from its having been made in a galvanized bucket.

This would seem to be quite sufficient for a five-cent glass of lemonade.

Vinegar is frequently sold in violation of the law, not so much on account of the presence of harmful adulterants but because in place of the more expensive cider vinegar one of the cheaper varieties has been substituted wholly or in part.

Olive oil is occasionally adulterated with cottonseed oil or other cheaper oils, but the number of such violations is a small fraction of that found several decades ago.

Preservatives in general have gone out of use, partly due to the enforcement of the food laws, but more generally due to the improved sanitary conditions which obtain in food packing establishments.

SODIUM BENZOATE

When the Food and Drugs Act was passed there were only one or two tomato catsup manufacturers who put up their products without preservatives, claiming to rely upon the soundness of the materials used and the maintenance of rigid sanitary conditions in their plants. By far the

greater number of manufacturers claimed, at a congressional hearing in 1910, that it was absolutely necessary to use sodium benzoate, which was then made one of the few permitted preservatives when used in a limited amount. Sodium benzoate was then selling at about sixty cents a pound. When, during the war, the prices of certain chemicals, usually obtained from Germany, soared to almost incredible heights, and when the price of sodium benzoate advanced to more than eight dollars a pound, it was remarkable how many manufacturers of tomato catsup, who had claimed that it was indispensable, found that they could do without it and have never gone back to it.

TRICKS OF THE TRADE

It is not generally known in this country that adulteration or substitution is frequently controlled in European countries by the intentional addition to certain articles of food and drink, of substances whose recognition by chemical or microscopical tests is extremely simple for the analyst or inspector. For example, potato starch is required to be added in very small amount to oleomargarine, at the time of its manufacture. Now, potato starch may be recognized by a microscopic examination which may be made by a trained inspector using a pocket microscope, or the presence of starch, generically, may be recognized by the same inspector by a very simple chemical test made in the presence of the seller. This effectually prevents the sale of oleomargarine for butter when efficient inspection of markets and stores can be maintained. In some countries which do not use the potato starch method of control, an easily identifiable fixed oil like oil of sesame is required to be added. This, too, can be quickly detected by the inspector.

Almost everybody nowadays is familiar with the name "phenolphthalein," for it is used as a laxative ingredient in petroleum oil emulsions, in chocolate blocks or other laxative confections and in laxative chewing gum. Few persons know, however, that the properties of phenolphthalein as a laxative were not discovered until many years after its introduction as a laboratory reagent. It belongs to the group of reagents known as indicators,, which substances have the property of showing a change in color at the conclusion of a chemical reaction. Phenolphthalein is colorless in acid solutions, but develops a brilliant red color in the presence of a small excess of alkali.

In Austria there are many fine varieties of grape wine, all of which have their imitations. In order to control the practice of substituting imitation wines for real wines the Austrian authorities re-

quired the manufacturers of the spurious wines, which had a perfectly legitimate market if sold honestly for what they were, to add a small quantity of phenolphthalein to these imitation products so that the inspectors of food and drink might with quickness and certainty distinguish by a simple chemical test between the genuine and the spurious. Shortly after this regulation went into effect the habitual drinkers of these spurious wines complained of continual diarrhœa, and upon investigation of the cause, the harmless laxative properties of phenolphthalein were thoroughly established and where ounces were manufactured in the past, hundreds of pounds are made today.

HOT PEPPER

An American employment of a similar indirect method of establishing the proof of an adulteration of pepper was the result of a startling and dramatic finale to a Federal prosecution some years ago. A well known firm of spice importers and sellers was prosecuted under the provisions of the Food and Drugs Act for having adulterated their ground black pepper with pepper shells. It so happened that they were importers of pepper shells, which have certain legitimate uses. The United States authorities, suspecting the illegal diversion of some of this imported material, had impregnated the shipments received by this particular firm with traces of an easily recognizable chemical which was harmless and which was easily identified in very minute quantities. After the accused firm had established what seemed to be a very good defense, through the efforts of its scientific staff, the United States authorities called in their chemists to testify to the presence of this particular foreign chemical in the defendant's pepper, and the defense wilted.

WATER SUPPLIES

Another fruitful field of work for the detective chemist is in that of water supplies and water contamination. Here it is customary for the chemist either to work hand in hand with the bacteriologist or to be trained in that field himself, which is preferable. An interesting and somewhat spectacular phase of such work is the tracing of sources of contamination of wells, reservoirs or springs. There are certain substances that can be added to a suspected source of pollution, such as a cesspool, which by communicating some specific property to water which it does not ordinarily possess, will appear as a distinctive factor

in a well, spring, or reservoir, if there is any subterranean connection leading from the cesspool thereto.

One such substance is kerosene, which if, when added to a cesspool, appears in the suspected water supply with its characteristic odor and flavor, proves conclusively the source of contamination. Another method is to add to the cesspool a chemical dyestuff known as fluorescein, which communicates to the water in the well, reservoir, or spring, a startling green fluorescence, which, while perfectly harmless in the amount used, is alarming to the users of the water.

Sometimes a large amount of salt is added to the cesspool, having previously determined the normal salt content of the water supply. Still another method is to introduce into the cesspool a chemical not usually found in drinking water, such as a salt of lithium, which may be detected by means of an instrument known as the spectroscope, the most delicate testing instrument known. The first and second methods described are the best to employ, for they usually bring about immediate cessation of the use of the contaminated water.

NARCOTIC CHEMISTRY

Another group of laws in which the trained chemist's services are indispensible are those connected with the control of habit-forming drugs. The most important of these drugs are opium and its principal derivative, morphine; cocaine, the alkaloid obtained from cocoa leaves; heroin, an artificial alkaloid related to morphine; and cannabis indica, also known as hasheesh, from which our word "assassin" is derived; this drug is also known to its devotees as "guaza," "bhang," and "marihuana."

COSMETIC CHEMISTRY

There is one group of substances for which no controlling laws as yet exist, concerning which the chemist is frequently retained in private damage results. These are the cosmetic preparations, of which the great majority are free from suspicion altogether, but there are two small groups in which harmful constituents are frequently found. These are the hair dyes and the freckle removers and skin bleaches. I have seen cases where the user of a hair dye suffered from a very unsightly and painful skin disease because of the presence of a chemical to which the user was particularly susceptible. Such susceptibility is called an idiosyncrasy, and no damages can be collected, as a rule, no matter how severe the injury.

Then we have the lead-containing hair dyes, whose users may not show any symptoms until enough lead has been absorbed to bring about a distressing condition known as chronic lead poisoning. The freckle creams frequently contain injurious amounts of mercury compounds. But a certain number of women, in their desire to make or keep themselves attractive, will run any risks, however dangerous.

DETECTION OF FORGERIES

Another fertile field for chemical services of great importance is that of false or fraudulent documents and letters. Here not only can the identity of the paper be established by microchemical tests, but by establishing such identity the period in which such paper originated is automatically proven. Prior to the ninth century vellum or parchment was used throughout Europe almost exclusively, paper not yet having been introduced from the Orient, and the use of papyrus having been practically confined to Egypt. Then the chronological periods of successive types of paper appear in the following order with the accompanying approximate dates: linen rag paper, ninth century; cotton rag paper, eleventh century; straw paper, 1800; wood pulp paper, 1840; esparto paper, 1860.

Inks likewise have their approximate dates of origin and may readily be identified by chemical tests. The earliest inks were carbon inks, or inks made from colored pigments held in suspension. The iron tannate, or nutgall ink, as it is commonly called, originated in the eleventh century; the indigo inks and the logwood inks in the eighteenth century, while the coal tar inks were not in use until the latter half of the nineteenth century.

Methods of staining papers by steeping them in coffee and similar decoctions to give them a fictitious appearance of age yield products which are also readily detectable by chemical means. An individual, therefore, who tried to palm off upon a purchaser of autographs, a holograph letter, let us say, of Queen Elizabeth, and who had written it with aniline ink upon wood pulp paper stained with coffee, would be out of luck if a chemist were called into the case, and instances of many such exposures are a matter of record and attempts at such deceptions occur not infrequently.

Besides the chemical methods for detecting evidences of alterations in documents, there are physical methods, such as the use of ultra-violet light. This phase of criminological work will be discussed at a later lecture in this series by my colleague, Dr. Sturmer.

It is a matter of interest, too, to know that graphite pencils date from about the sixteenth century, prior to which time metallic lead styluses were used for writing on paper, hence the erroneous name "lead pencil," which persists after three centuries of use of a substance other than lead.

Alterations or erasures in handwriting itself and even the sequence of strokes are demonstrable by microchemical tests, and the field of invisible inks (sometimes called sympathetic inks) for secret writing, is a chemical problem from beginning to end, and the use of such means of communication played an important part in the secret service work of all of the participating nations in the World War.

The identification of cloths and fibres is another important field of detective work for the chemist, as is the detection of counterfeit bank notes and spurious coins.

One of the recent bits of chemical research which aids in the identification and recovery of stolen automobiles is rather remarkable. Although the engine number of a car, which in many cases is stamped into the metal of the engine body by pressure, may be filed away and an entirely new and different number stamped in its place, the original number may be brought out with distinctness by exposing the area involved to the action of certain chemical vapors.

I think that by this time I have covered a sufficiently large field and given enough examples to prove that the chemist may very well be classed as a detective in connection with law enforcement although he does not don gum shoes and false whiskers as the fiction detective used to do. Even a knowledge of the composition of dust and dirt may play an important part in the detection of crime, much in the same way in which such data were used by the versatile Sherlock Holmes. But there is this important difference between the chemist as a detective and the private or official member of the orthodox crime detecting fraternity. The chemist has extra responsibilities in connection with the receipt and custody of the sample or samples, and he is not only a witness in the ordinary sense but actually acts as an expert witness as well.

THE EXPERT

In discussing this phase of the subject I would like you to disregard several humorous definitions of an expert witness. One of these is that the expert witness is a professional man away from home; the other draws an unpleasant comparison between liars, damned liars, and expert witnesses. Another

reproach is in connection with the definition of a specialist as one who knows more and more about less and less. This is not true of the detective chemist, whose field of work is broader than that of any other in the profession and who must also possess imagination and a knowledge of thousands of unrelated facts, any one of which may help give the clue to the problem for whose solution he is searching. This field of chemistry in the service of the law is sometimes called "forensic" chemistry.

It must always be remembered that the burden of proof is on the accuser in a criminal or other legal prosecution. The chemist, of course, may figure on the side of either the prosecutor or the defendant. He deals with facts primarily, scientific facts, of course, that are capable of proof, and on the basis of these facts he may make deductions and express opinions, this constituting him an expert witness and distinguishing him from the ordinary witness who is confined to facts only and who may not make deductions or express opinions. This is a great responsibility in itself and the chemist who lives up to the ethics and ideals of his work will never be a partisan but will give his testimony impartially and without bias.

One of the most important factors in chemistry as it pertains to the criminal law is the sample or specimen taken for analysis. The collection of the specimen or sample is not often under the jurisdiction of the chemist. When it is not, the transfer of the sample must be made in person and not through an intermediary. The chemist, as the custodian of the sample or specimen, must then keep it in such a manner that it may not be tampered with until he appears with it at the trial of the case. In other words, there must be no lapse of continuity from the time the specimen is taken until it is offered in evidence.

An interesting story is told of a certain district attorney who had been charged an exorbitant fee by a chemist with whom he had not made an agreement before the trial as to his charge for his services. The chemist and the district attorney, it may be said, lived at opposite ends of a large state. Several years thereafter the district attorney sent one of his assistants to this same chemist with an important specimen which was connected with a case of alleged murder. After the preliminary discussion of the case, and after the chemist had stated what his fee would be for the analysis of the specimen and attendance in court, the messenger casually asked the chemist if he would keep the sample until he, the messenger, went

back to the hotel and discussed the fee with the district attorney. The chemist consented, and after an hour or so the messenger returned and said that the price was too high and asked for the return of the sample which he took back to the district attorney, who then made satisfactory arrangements with another chemist. When the case came to trial the first chemist was surprised to receive a summons, not as an expert witness, but as an ordinary witness whose testimony was needed to prove the history of the sample, and for which he would be entitled only to mileage and a nominal witness fee. It was a bitter pill for the chemist to swallow but there was no evasion possible, and he had to spend three days in traveling and court attendance for bare expenses in order that he might account for the custody of the sample for a single hour.

The chemist must know, not only how to analyze the sample, but he must also be cognizant of certain chemical changes which might take place in a sample between the time of its collection and its delivery to the chemist. In samples of suspected beer, for example, where the alcoholic content might increase, it is now customary for the agent who collects the sample to place a bichloride of mercury tablet in each bottle of alleged beer before sealing it, thus precluding the possibility of the sample increasing in alcoholic content before its examination by the chemist, which would be an injustice to the defendant. It will be realized that a chemist's samples are not to be recklessly tasted.

The chemist is responsible, of course, for the decision as to the character of the analysis, and also for the selection of the method or methods to be followed. Without going into the technical details it may be stated that an analysis may be proximate or ultimate, partial or complete, direct or indirect. Most analytical methods have been standardized and are recognized as authoritative. Many occasions arise, however, when the chemist must improvise or develop a new method, which entails some preliminary research, and he must be prepared to defend this method in detail upon cross-examination.

It must be remembered that in giving his direct testimony, as well as in cross-examination, the chemist must testify in non-technical language as far as possible, not only for the sake of the jury but for the judge and attorneys as well. It will always be found that the chemist who succeeds best in this difficult task is the one whose services are most frequently in demand.

The chemist may also use his detective ability and frequently does so in civil cases, such as those involving patents and their claims, breach of contract for supplies sold on specifications, accidental injury from incorrect filling of a prescription in a pharmacy, or poisoning from unwholesome food consumed in a restaurant or hotel. There is no single group of chemists in this country corresponding to the Public Analysts of Great Britain, who are the most highly trained (and poorly paid) group of public servants in the world.

Utilization of the possibilities, not only of chemistry, as has been outlined in the foregoing, but of all scientific methods, is being made in Berkeley, California, by Chief of Police Vollmer of that city, who has made an international reputation for the systematic and continuous use that he has made of scientific methods in the detection of crime. Chief Vollmer has personally reorganized the police departments of a number of cities in our country and also in Havana. He is now conducting a course on his methods in the University of Chicago, a department which is called the "School of Criminal Investigation."

An American pharmaceutical chemist, who I am told was a friend of Chief Vollmer, and who devoted much of his scientific ability in aiding in the detection of crime up to the time of his death less than a year ago, was Professor Albert Schneider, of the School of Pharmacy at Corvallis, Oregon.

One of the most splendidly equipped laboratories in the eastern part of the United States for the work of scientific crime detection is in our own new city morgue, and is under the direction of Coroner's Physician Dr. William S. Wadsworth, who is a brilliant example of an internationally known scientific expert engaged almost entirely in crime detection. The Nestor of detective chemists in this section of the country, at least, is Dr. Henry Leffmann, whose knowledge of the subject is remarkable and whose experiences would inspire many interesting books, and who is also internationally known as a chemical expert.

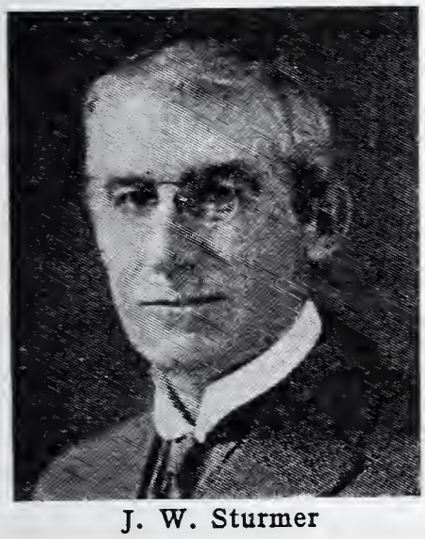
There is more widespread recognition of the important relation between science and the detection of crime in European countries than in America. For more than a score of years courses in "Criminalistics" have been given in the Universities of Prague, Bucharest, Lausanne, Liege, and other prominent universities. A dozen or more individuals in Europe have international reputations as scientific criminologists, and the criminal investigation department of Scotland

Yard, known to readers of detective fiction as C. I. D., is very much up to date in scientific methods applied to criminology. The Parisian Surete stands equally high in this field and the great Alphonse Bertillon was officially connected with the Department of the Seine as anthropometrist in particular and scientific expert in general, for his testimony in connection with the authenticity of documents was an important factor in the celebrated Dreyfus case.

UNDER INVISIBLE LIGHT

By Professor J. W. Sturmer

IT IS CUSTOMARY and natural to associate light with visibility, for our common ideas concerning light are purely subjective; they hinge upon our own sense-perception. Light, if we make this approach, is a manifestation of which we become cognizant through our optic organs, our eyes, an interpretation which leaves us completely in the dark regarding invisible light.



J. W. Sturmer

Indeed, this latter term which is not scientific but journalistic and popular, is absolutely meaningless if we do not for the moment forget our ideas concerning light as arrived at subjectively, and think of it objectively, as a form of radiant energy. If now we also accept that all forms of radiant energy are fundamentally alike, and that their dissimilarities are attributable to differences in vibration frequencies, or, as we might put it, in wave-lengths, we can draw upon our knowledge of radio to help us to a clearer understanding of the term invisible light. Suppose we think of our eyes as a kind of radio receiving set, one capable of "tuning in" all transmissions within a certain range. It is clear that any transmission outside of this range would not be receivable, notwithstanding the fact that it comes over the air in the same way, and is fundamentally identical with the transmissions which we can "tune in." Similarly, human eyes are responsive to certain light waves and not to others. The range, when it comes to reception, falls within a certain span of vibration frequencies, or, using the common expression, of wave-lengths.

RANGE OF INVISIBLE LIGHT

Now invisible light, or ultra-violet light, is radiant energy in wave-lengths which our eyes cannot tune in because the waves are too short and the frequencies too high. They range from the shortest waves which we can see, the violet, downward to waves only one-fourth that long. The wave-lengths of invisible light, and the shorter ones, are so minute that

our ordinary units of measure are impracticable, and special units had to be established. The unit most generally employed is named in honor of a Swedish scientist by the name of Ångström, and so it is called the Ångström unit, usually abbreviated Å. We shall use this unit.

LIGHT AND COLOR

In terms of Ångström units visible light—so-called—ranges in wave-lengths from about 3700 Å to about 7700 Å. When all these wave-lengths are represented, the light is without color, like daylight. White light may be separated into certain components which then exhibit color, the colors of the rainbow. But it should be understood that a rainbow color is not attributable to a single wave-length, but to a range of them. Thus violet light comprises the shortest visible range, from about 3700 Å to about 4300 Å; blue, from 4300 Å to 4900 Å; green, from 4900 Å to 5750 Å; yellow, from 5750 Å to 5850 Å; orange, from 5850 Å to 6500 Å, and red from 6500 Å to the end of the spectrum, which is about 7700 Å. We are careful to say "about" because there is no sharp line of demarcation, and the colors overlap and diffuse into each other. Moreover, the receiving mechanism, the human eye, varies, so that no two observers can agree where one color effect ends and another begins; nor can they agree on the exact limit of visibility.

But somewhere in the neighborhood of 7700 Å the visible rays melt into invisible heat rays, while wave-lengths shorter than approximately 3700 Å are also incapable of producing, in ordinary media, the phenomena of light. Thus light radiation represents a rather narrow span in terms of wave-lengths of radiant energy.

At this point someone may ask, "Do we actually see this radiation called visible light, or do we see its effect on matter? If we could be transported into empty interstellar space, could we really see a ray of what is called light?" In answer let us admit that the manifestations of light always involve material media. When light travels through empty space, as from the sun to the planet on which we live, it is merely a stream of energy—a stream of electrons, if we like—which leaves the empty space in darkness. But when it encounters the atmosphere which envelops the earth, it does something to the gases and vapors and solid particles in this atmosphere, and light-phenomena become manifest to the human eye. The clear sky becomes blue. Vapory clouds appear like balls of cotton, while the eastern sky at sunrise, and the western, at sun-set, may appear orange and

red, with the fleecy clouds gorgeously embroidered with gold and tinted with rose and amethyst. Earth and rocks and vegetation respond with an exhibition of colors, colors which we know are associated with what is called light. Invisible light does not produce these effects.

SELECTIVE ABSORPTION OF LIGHT RAYS

We explain the tints observed in nature, the green of vegetation, the orange, yellow and red of autumnal foliage, the colors of flowers, on the theory of selective absorption, the colors which we see being depended upon the wave-lengths of light which are not absorbed, but are transmitted and reflected. Invisible light leaves our vegetation in total darkness.

Now what do we mean by absorption? What happens to the wave-lengths of light falling upon a green leaf and not appearing as a green color? We know that in this case some of the wave-lengths are expended in producing chemical changes within the leaf, changes which we speak of as photo-synthesis. Let us bear this fact in mind: radiant energy may do chemical work, and thus disappear. Next let us note what happens when some soot or lamp-black is placed on a cake of ice, and this is exposed to sunlight. We find that in the neighborhood of the black substance the ice melts much faster. Obviously, some of the light rays have been transformed into heat rays, which means that their frequencies have been stepped down, and their wave-lengths increased. Somehow the lamp-black has brought this about. The light rays apparently have set up a disturbance resulting in a vibration giving rise to the longer wave-lengths which are manifest as heat, but which are not associated with light-phenomena. The light has become invisible, become invisible because of a change in wave-lengths. It is common knowledge that much of the sunlight disappears in this manner—in rocks, in earth, and in vegetation.

ABSORPTION OF ULTRA-VIOLET

But sunlight comprises a great range of wave-lengths—light rays, heat rays, and the ultra-violet rays, which we know are invisible. When these latter are absorbed, do they also disappear, either by undergoing a change of wave-lengths, or by doing chemical work? Let us see.

Witness the life-guard on the beach at the seashore. When he enters upon his duties in early summer, his skin is light in color, like yours and mine; but before many days a skin pigment called melanin, develops and that portion of his body which is not covered by his

bathing suit, becomes tanned a deep brown, or, it may be, he develops freckles almost as dark, and almost as large, as gingersnaps. It is evident that the sunshine causes the pigmentation, and it is known that certain wave-lengths, falling within the range of ultra-violet radiation, namely those from 2800 Å to 3300 Å, are responsible for his coat of summer tan. In other words, these rays are absorbed by the skin, and they disappear in chemical activity, just as certain light rays are used up in photo-synthesis when sunlight shines on a blade of grass. We have visual evidence of the production of the skin-pigment, melanin; but other chemical changes are caused by ultra-violet rays, and not all such changes result in the production of pigment. There is, for example, the formation of vitamine D which gives evidence of its presence by its tonic effect on metabolic functions, but which does not make its presence known to our vision as does melanin. There may be yet other chemical results of sunshine. Indeed, a considerable portion of the ultra-violet from the sun may be expended in chemical activity.

FLUORESCENCE

Now let us see what happens if our life-guard on the ocean beach takes to the use of skin cream. That certain ointments and cold creams effectively prevent tanning is well known. Obviously, these preparations must intercept, that is, must absorb, the pigment-producing rays. If so, there must result chemical action, or, if this is not the case, there must occur a lengthening of the wave-length, comparable to the effect noted in connection with the black paint or soot on ice. There is, however, this difference: if light rays are lengthened, invisible heat rays result; but since ultra-violet rays are shorter than light rays, their "step-down" may involve the production of wave-lengths which fall within the range of the visible spectrum, and thus out of invisible light there might come visible light. Now this is precisely what happens when ultra-violet rays are absorbed by a tan-preventing skin cream. We may prove it by means of our ultra-violet lamp, provided with a filter to intercept visible rays and passing only the invisible rays. Under such radiation the skin cream becomes luminescent. It appears that the invisible radiation has set up a disturbance in certain components of the skin cream resulting in the emission of wave-lengths which our eyes can perceive, and thus the ultra-violet rays have lost the characteristics by virtue of which they produce skin-pigment. They have ceased to be ultra-violet rays. They are now visible light rays, with the properties

of such rays, and without the properties peculiar to the shorter ones denominated invisible light.

WHAT CAUSES FLUORESCENCE?

Scientists have given much thought to the astonishing phenomenon of luminescence, or fluorescence, as it is commonly called, involving the stepping down of invisible to visible light by certain substances. How does this happen? Why do certain chemicals function in this manner while others do not? The answers to these questions are not very satisfactory. But let us bear in mind that we do not as yet understand fully why a pigment shows its characteristic color by selective absorption of certain wave-lengths and the transmission and reflection of other wave-lengths. As regards fluorescence, the hypothesis generally given connects the phenomenon either with the peculiar rotation of the molecule, or with the vibrations of the atoms within the molecule, or with the orbital displacement of electrons within the atoms, the assumption being that the impinging radiation effects their displacement, and that when the electrons drop back to their proper orbit or shell, they set up a radiation in a longer wave-length. Thus there may be at least three ways in which a substance may emit light rays when it is irradiated with invisible light. Fortunately we need not explain fluorescence before we can make practical use of it. We need but know certain facts, and with these as a basis we can make progress pending the time when science can give its final answer to the question how a chemical actually functions when it converts invisible wave-lengths into longer ones which we can see. Let us say simply that fluorescence is an induced emission, induced by ultra-violet radiation.

FLUORESCENCE COLORS

At this point we may with profit hark back to the statement that white light is made up of a span of wave-lengths, namely from about 3700 Å to about 7700 Å, and that its component colors embrace a range of wave-lengths. If now a substance under ultra-violet radiation emits all the wave-lengths from 3700 Å to 7700 Å, and in the proportion in which they occur in daylight, the fluorescing substance will appear white. Teeth, bones, and the whites of our eyes, emit white light under such conditions. Teeth, under ultra-violet rays are surprisingly white, whiter than in daylight, whiter in fact than we see them in a toothpaste advertisement. But a relatively small number of substances exhibit white fluorescence. More often there is color, which means that the range of wave-lengths of the emitted rays from the fluorescing

substance represents but a portion of the visible spectrum. Thus a fluorescing substance may appear red, yellow, green, blue, or violet, and its fluorescence color is an inherent property just as is its color, or the lack of it, in daylight. As a consequence, the appearance of a substance under ultra-violet may give a clue of its identity, and one substance may be distinguished from another, even though this be impossible in daylight. White lead, zinc white, chalk, and titanium oxide look very much alike in daylight; but not under ultra-violet radiation. Two dyes may appear to be of the same shade of red, but when we look at them by invisible light the one may be dark and the other a brilliant orange.

DELICACY OF FLUORESCENCE TESTS

The quantity of a substance required to produce an observable fluorescence effect is in some cases surprisingly small, and dilutions of 1 part to a million may disclose the presence of the fluorescing substance under ultra-violet light, and without the employment of tedious separation processes. Thus there is made available to the chemist a new technique in the detection of adulterations and admixture, and also of minute quantities of impurities.

OTHER ADVANTAGES

There are several advantages attached to the employment of fluorescence as a means of identification, or for the purpose of distinguishing between one substance and another. There is, first of all, the time factor. When conclusions are based on color, such conclusions may be arrived at "on sight", just as we distinguish between a ripe and an unripe banana, or draw our inference from the color of a man's nose. Secondly, no preparation of the material is required. All we need to do is to look at our substance under the ultra-violet lamp. Third, which is most important in certain cases, examination of a substance under the ultra-violet lamp does not destroy the material or make it useless for other chemical tests, or for other purposes. At least this holds true when the exposure to the ultra-violet light is of short duration.

TYPE OF ULTRA-VIOLET LAMPS

We have various types of ultra-violet lamps. There is the well-known health lamp, intended for therapeutic use in the household. This type of lamp is designed to replace sunshine, and to furnish the ultra-violet rays which are operative in producing vitamine D by their action on the sterol-like constituents in the skin tissue. Such a lamp cannot satis-

factorily be employed in fluorescence tests. There are also lamps of the carbon-arc type, or with carbons impregnated with iron or some other metal, which are capable of furnishing a wide range of ultra-violet radiation, including the waves shorter than 2000 Å. This is the type preferred when the ultra-violet rays are to be used in causing or in accelerating chemical change. But when the lamp is to supply the radiation for fluorescence the quartz tube mercury-arc lamp is a favorite. This lamp must, of course, be provided with a filter to intercept the visible light emitted by the mercury vapor arc. The filter, being of glass of special composition, and embodying nickel and possibly other metallic coloring agents, intercepts also some of the ultra-violet radiation, thus cutting down the intensity, and indeed, cutting out certain wave-lengths altogether, mainly those shorter than about 2800 Å. We can readily understand, now why a filter is not employed when the ultra-violet radiation is used to kill bacteria, or when it is used to cause or to speed up chemical changes. But for fluorescence work the filter is essential, and is always employed. This means that our data concerning the fluorescence of substances pertains generally to ultra-violet radiation of wave-lengths ranging from 2800 Å to the visible spectrum, that is to about 3700 Å.

MINERALS UNDER ULTRA-VIOLET

When we examine minerals under such radiation we find that certain ones, particularly, fluorite, calcite, and willemite, exhibit rare beauty of color; the fluorite is colored violet blue, the calcite cherry red, and the willemite shines with a yellowish green light. These three minerals thus cover, in their fluorescence, the whole spectrum from red to violet. We cannot explain why calcite steps down the ultra-violet to light of wave-lengths in the neighborhood of 7000 Å, while fluorite yields much shorter waves, those of violet and blue. We know only that each functions in this particular manner. Sometimes the fluorescence of a mineral is due to the presence of an impurity, in which case different samples of the same mineral may differ in color under ultra-violet light. It is, however, unnecessary to employ this radiation to identify minerals.

INORGANIC CHEMICALS

Inorganic chemicals are, speaking generally, not striking in fluorescence effect. Some, however, are. The uranyl salts, which show a brilliant green, and the double salts of the alkali metals and of platinum, are such notable

exceptions. Calomel appears brick red and a very small amount of this mercurous salt as a contamination of corrosive sublimate, can be detected instantly. Strange to say, when calomel is heated, it loses its power to fluoresce, but regains this property on cooling.

ORGANIC CHEMICALS

In organic chemicals the property of showing fluorescence is so common, and possessed by so many compounds of this class, that we seldom can depend on this characteristic to establish identity. We may, however, use it in disclosing a suspected admixture or impurity. Thus we can detect small quantities (about 1 per cent.) of acetone in alcohol; traces of benzoates or salicylates in food products. One may tell also, at a glance, whether a confection contains coumarin or vanillin, and if a cologne contains oil of neroli.

Most alkaloids fluoresce strikingly, which makes their detection possible even though the quantities present be exceedingly small. Thus quinine sulphate shows its presence in the saliva for several days after the last dose has been taken, shows it by its bluish fluorescence, while fluorescein may be detected in solution of 1 part to a million.

Many of the coal tar products fluoresce; naphthelene, anthracene, phenol, hydroquinone, pyrogallol, beta-naphthol—and scores of others. Anthracene, in chloroformic solution, shows a purple color, while the anthracene in crystals shows green. A striking effect is produced under the ultra-violet when anthracene solution is allowed to evaporate to dryness from filter paper.

Fixed oils, fats, and waxes exhibit characteristic fluorescence colors, which fact may be utilized in their examination for purity as well as for their identification. The same holds true for a number of the volatile oils. Lubricating oils from petroleum, and also petrolatum, are strikingly fluorescent.

CRUDE DRUGS

Many crude drugs fail to show characteristic colors under ultra-violet. There are, however, a few which do give beautiful color-effects. The most conspicuous drug under this radiation is hydrastis, which glows like burnished gold. It is interesting to note that its synonym is golden seal, a name chosen long before anything was known about the golden-yellow fluorescence of this drug. The rootlets, as well as the rhizome show the effect, but only upon fracture, for the epidermal tissue absorbs the radiation without the show of color. The golden glow of golden seal is due to

the alkaloid berberine. The other alkaloid, hydrastine, appears white, like snow does in certain light, namely white with a faint suggestion of blue. Speaking of vegetable matter in general, and of drugs in particular, it is important to bear in mind that the fluorescence observed may be due to a single constituent. If this constituent is peculiar to a single drug, the fluorescence has diagnostic value. If, however, the fluorescence is due to a constituent which is common to many drugs, we must draw our conclusions with great caution. As a case in point we might mention chlorophyll, which is, of course, present in all leaf-drugs. Now chlorophyll, when it has been extracted without chemical transformation, and has been taken up in aqueous ether, shows a beautiful red color—a rose red. But such a color effect under the ultra-violet could not be used to distinguish between peppermint and spearmint, uva ursi and buchu, digitalis and belladonna, for all green plant substances would give the same color, as all contain chlorophyll.

BLOOD STAINS

The chemist sees a relationship between the green pigment of plants and the red pigment of blood. It is interesting in this connection to note that under the ultra-violet the chlorophyll solution looks like a high dilution of blood. It is of further interest that while blood does not fluoresce, it can be made to do so by treatment with concentrated sulphuric acid, and subsequent dilution with water, when it develops a rose-red fluorescence indistinguishable from that of chlorophyll. This fact has been utilized in the detection of blood spots.

FLUORESCENT INDICATORS

Some fluorescing substances, as has been stated, may lose this property on heating, or on undergoing solution; others may lose it in the presence of an excess of acid, or they may exhibit it under acid conditions, and lose it in the presence of excess of alkali. Quinine is such a substance: blue in acid solution, and colorless in alkaline liquids. Indeed, this alkaloid has been employed as an indicator in volumetric analysis, the procedure being, of course, carried out under ultra-violet radiation. Another substance affected by acids and alkalies, and hence useful as an indicator, is umbelliferon, a constituent of the gum-resin galbanum. This interesting plant principle is fluorescent in alkaline solutions, showing an intense greenish luminescence, which effect disappears when the alkali has been neutralized with acid. Umbelliferon has been used

in the titration of dark fruit juices, in which cases the ordinary color-changing indicators are useless, as their colors are obscured by the deep colors of such juices. Umbelliferon seems to be fairly permanent, remaining unaltered in medicinal mixtures through long periods of time. A sample of a very old plaster, containing galbanum, found in the collection of the Philadelphia College of Pharmacy and Science, and made by students probably prior to the Civil War, was found to disclose its umbelliferon content to the ultra-violet lamp.

IN PLANT HISTOLOGY

In pharmacognosy and plant histology, the ultra-violet lamp may at times be employed to advantage to show where certain constituents occur in the plant tissue. If, for example, a cross section is cut from a twig of the horse chestnut tree, the aesculin discloses its presence in the inner bark by its brilliant fluorescence, and one may see at a glance that this plant principle is not uniformly distributed throughout the plant tissue.

FOODS

An extremely interesting use of the ultra-violet lamp is in connection with the examination of foods. Not only may it be used to distinguish between the genuine and the spurious, the pure and the adulterated, but it may be employed also in some instances to determine whether the foods are fresh or stale, this being possible because the chemical changes which certain foods undergo on keeping alter their fluorescence under ultra-violet light. Fish, for example, show such changes under the invisible light before phosphorescence develops, and before a putrescent odor may be observed. The lamp shows before the nose knows.

OTHER APPLICATIONS

There are countless other applications of the ultra-violet light. Thus one may distinguish, at a glance, between silk and artificial silk, ivory and celluloid imitation, white lead and zinc white, precious stones and paste, beeswax and cerasin, true parchment and parchment paper, natural teeth and store teeth—if circumstances justify the disclosure.

CHECKS AND PAPER MONEY

The modern banker may employ the invisible light to determine whether a check which is under suspicion has been raised, whether a five-dollar bill is Uncle Sam's own production, or is counterfeit. To understand how

light may be thrown upon the genuineness of paper money, checks, and documents, it is but necessary to know that practically every variety of paper stock has a fluorescence which is characteristic, dependent upon the sizing, the mineral filler, and other constituents found in modern paper. Thus resin, casein, and glue contrast with each other, and so do the various mineral substances employed as paper filler. Moreover, the inks, even those which appear to be of the same color in daylight, are readily distinguishable under the ultra-violet lamp. And as for altered checks, these may be spotted at once, for not only do erasures, even clever ones, become quite conspicuous, but bleaching fails to achieve its purpose, for the ink which has been made to disappear, shows up under ultra-violet light. A check which has been subjected to a clever bleaching operation, so that a higher number may be inscribed, need not fool an up-to-date banker.

IN CRIME DETECTION

And in a similar way, the art collector may now use the ultra-violet lamp to determine whether a painting offered as the work of one of the old masters, is that in fact, or is a clever copy. We can imagine also how A. Conan Doyle could have found use for the ultra-violet lamp in connection with crime detection in his Sherlock Holmes stories. Indeed, not only in fiction, but in actual practice the ultra-violet lamp has become a tool for the modern detective.

CONCLUSION

And all these uses of the ultra-violet lamp, as well as many others which we cannot here enumerate, hinge upon the fact that certain chemicals function characteristically when they are subjected to the ultra-violet rays comprising the wave-length from about 2800 to 3700 Å, rays which are not visible, but which by these chemicals are stepped down to longer wave-lengths, resulting in the appearance of color, a phenomenon known as fluorescence.

IODINE—THE "ELEMENT OF DOUBT"

By Ivor Griffith, P. D., Ph. M.

THE YEAR 1776 infected a great many people with notions of independence. Jean Baptiste Courtois, a volatile Frenchman, citizen of Dijon, was one of them. For years he had served as valet to a wealthy family in the suburbs of Dijon. In 1776 his former neighbor, Guyton de Morveau, offered him a job as general factotum in his chemical laboratory at the Academy of Dijon. Courtois, familiar with army titles, may have thought that a "general factotum" ranked highly. He soon learned, however, that in the language of the laboratory, a "general factotum" meant nothing less than chief cook and bottle washer.

Ivor Griffith

Yet he stuck to his new job for several years. His employer, Guyton de Morveau, had been Courtois' neighbor and boyhood chum. Only—while Courtois had early entered into family service, his chum had gone to school to study law. And soon he had opened his law office.

Every day in every way he seemed to grow wiser and wiser, busier and busier, richer and richer. And his friend Courtois envied him—envied him still more so when he learned that De Morveau, alive to the fashion of the day, had installed in his home a full fledged chemical laboratory.

For in the best circles of France, in those days, torturing chemicals with fire was a very stylish hobby. Indeed so enamored did De Morveau become of his new avocation, that he began to neglect his law practice and his friends began to worry about his future.

Until—until one Monday morning they read with amazement an announcement which appeared in glaring headlines in the front page of the Dijon *Daily News* to the effect that Guyton de Morveau had been elected by the Board of Trustees of the Dijon Academy to the important post of Professor of Chemistry.

Now in those days a Professor of Chemistry had unlimited possibilities. He could say most anything about Chemistry—and no

one knew whether he was right or wrong. And he was no fool specialist—for every field of chemistry was his pasture.

THE LAWYER PROFESSOR

And so Guyton de Morveau deserted the cause of justice and became Professor of Chemistry, Organic, Inorganic, Synthetic, Analytic, Forensic, Physical, Colloid, Pharmacological, Physiological and every logical and illogical kind of chemistry, then known, unknown, practiced and promised.

Of course, so little of chemistry was understood in those days that a lawyer, with a good flow of language, could so well dilute a little knowledge with his flood of words, that a Board of Trustees could be easily fooled. But De Morveau did better than that. Indeed he became a still greater chemist and professor than he was a lawyer —and his name will live so long as chemistry lives—not because he gave Courtois, the elder, a job in his laboratory, but because of the many discoveries he made for himself and for posterity.

Although a little way from our subject, of interest perhaps, will be a brief discussion of the status of the science of chemistry in the days of Professor de Morveau, that is, admitting that such chemistry as was then known deserved the title "science."

Still, one wonders if a century hence, the same may be said of the chemistry of 1930—and its chemical professors and its chemical performances. For as truly as we think we have cause to marvel today at our ninety-two elements and their million combinations, and at our so-called chemical progress—so truly will some fresh popular lecturer on Wednesday evening, February 19, 2030, when we will all be silent in dust, laugh publicly at our ignorance, and wonder why we had failed to see what to him, then, will be ever so obvious—and why we had failed to understand what to him, then, will be ever so evident.

The chemistry of 1776 still bore the mark of the alchemists, those queer quacks who mixed religion with their experiments, and scratched the sign of the cross on all their utensils. In justice to these old fellows however, it might be said that the two great riddles which they so long and so vainly sought to solve, are still unsolved, in spite of split atoms and loosened electrons. Their "philosopher's stone," wherewith they hoped to change the baser elements to gold—and their "elixir of life" with which they fain would find perennial youth are still elusive mysteries.

Some may have thought that the *Philosopher's Stone* had been found in Wall Street—but remember November. And the nearest we have ever come to the *Elixir of Life* can only be had on prescription.

THE GUESSES OF THE GREEKS

It had taken over a thousand years to upset the guesses of the Greeks that all matter was composed of four elements managed by a fifth—the quintessence. Air, earth, fire and water constituted the quartette—life was the band-master—the quintessence.

But in the days of which we write the vapid mist which had so long pervaded the field of chemistry was beginning to condense on the cold dome of research and reason—and observers were just beginning to contemplate the vast domains before them.

A dozen or two of the elements had been discovered—and the old quartette of the Greeks forgotten. *Air* was now known, thanks to Scheele and Rutherford, as a mixture of oxygen and nitrogen. *Fire* was recognized by Rumford. *Water* was soon thereafter analyzed by Lavoisier and synthesized by Cavendish—and *Earth* was full of possibilities.

The Tria Prima of Paracelsus, too—and the fashionable phlogiston theory had been explained away willingly or otherwise by Geoffroy, the French apothecary, and Priestly—the Lancaster County preacher. And it had come to pass that element hunting was now the popular pastime of Europe's elite.

But let us now return to Courtois and the Professor. Through the latter's influence the erstwhile valet and general factotum secured a new post as manager of a saltpeter factory. Now in those fighting days the saltpeter business was a busy business, for niter was an ingredient of gunpowder—and tons of this pleasing commodity were being daily used to reduce to a minimum and to poverty, the population of certain parts of Europe.

IODINE—BORN 1812

To this saltpeter factory for a little time came his son Bernard—and this is the Courtois whose name will be associated with chemistry as long as chemistry persists. For it is he who is credited with the discovery of Iodine, that evanescent element, that friendly element, that popular element,

which of all the solid elements of universe least likes to live in loneliness.

Early in life Bernard Courtois was apprenticed to Fremy, pharmacist at Auxerre, after having had a short preliminary training at the Polytechnic. Serving in the war of 1799, he later joined Thenard. This is the famous apothecary who discovered hydrogen peroxide—and so made it possible for gentlemen to have their preferences.

Still later we find him with Sequin, who is remembered for his researches with opium and cinchona. Here in 1802 he isolated a crystalline compound from opium, no doubt morphine, but a peculiar timidity inherent in all his performances, kept him from announcing its discovery.

And a few years later Sertürner (1815), an apothecary of Einbeck,* earned an everlasting name when he proclaimed to the world the independent discovery of morphine—and thus achieving to a distinction which might have been Courtois' had his timidity complex not ruined his chances.

A CHANCE ACQUAINTANCE

On the death of his father Courtois retured to his niter factory. There it was, in 1812, while washing the ashes of seaweed which were used as a potash source, and destroying certain impurities with vitriol, that he first noted the violet fumes which later revealed to him iodine—a substance which, on condensing, caked upon and corroded his pans.

His discovery was communicated through his friends to the Institute in Paris. Gay-Lussac, Ampere and Chaptal further studied the new substance which neither Courtois nor his friends had actually called an element.

It so happened just about this time that Sir Humphrey Davy, with a special permit from Napoleon, enjoyed the freedom and perhaps the follies of Paris—and went about its learned circles grasping eagerly at every novel act and thought. He was told of Courtois' violet vapor and he at once suspected it to be elemental in nature and was soon able to confirm his suspicions. Gay-Lussac too, simultaneously arrived at the same conclusion, and submitted his findings in a paper read before the Paris Academy just a few shopping days before Christmas, 1813.

*The little town that gained renown for its far-famed beer, the *Bock*.

Thereupon, so we are told, but not by Sir Davy's biographer, that the versatile Englishman Davy and the volatile Gay-Lussac of France, entered into a strenuous wordy battle as to the priority of their discoveries—the poor apothecary's clerk of Dijon and his saltpeter factory for the time, being, completely ignored. In France, Gay-Lussac had the victory. In England, Davy won.

However, all chemical authorities today honor Bernard Courtois, not Davy, nor Gay-Lussac, for the discovery of the ever important sublimable element *iodine*. Davy has credit enough with his lamp, and Gay-Lussac with his law—let alone the discovery by the former of chlorine, of sodium, of potassium, and by the latter of many fundamental laws of the science.

IODINE—BAPTIZED

To Davy however, goes the honor of having baptized this chemical infant, iodine. The name he chose is derived from the Greek word (ιωδης) meaning violet-like, and which itself is compounded from two Greek words ιον (a violet) plus ειδος (form)—the Latin *viola* being a corruption of the Greek. Thus it is seen that because of the color of its vapor, iodine is named after the modest violet, whose perfume constituent is quite properly called ionone.

Etymologically it is interesting to note in passing that the word iodine has a common ancestry with the word idol and idyll.

Rather true to type was Courtois' death. Like many another pioneer and benefactor of humanity, he died a pauper—the dawn of peace having ruined his saltpeter business, and the six thousand francs which the Academy of Science had awarded him for his discovery having been vainly spent trying to redeem his failing business.

Iodine belongs to that class of simple elements, captained by hydrogen, and thus, unlike its cousin chlorine, exhibits no isotopes. Because of its special salt engendering and other properties, it is grouped in that famous chemical quartette the halogens, chlorine, bromine, fluorine, being the other three members. Of the four—iodine is the only solid, fluorine and chlorine are gaseous, and bromine a heavy liquid.

It is interesting to note here that one of the two remaining undiscovered elements is known to have such chemical properties as will bring it into the halogen group. Just now it is called No. 83—for lack of a better name.

IODINE—AT HOME

America draws most of its crude iodine from one source—Chile, where iodine occurs as sodium iodate associated with crude nitrate of soda or caliche. This source of supply is ample to fill all of America's present need for the element. In Japan a hundred tons are annually produced as a by-product in potassium chloride manufacture from kelp or seaweed. half of which is exported to Russia.

Java has recently come to the fore as a potential source of iodine. Copper iodide an ore native to that country, is now on the free list of the proposed tariff bill, and Javanese iodine may be soon in competition with the Chilean product.

Another source that promises much are the brine wells of the oil producing regions. In Sand Springs, Colorado, an American company has been organized to recover the iodine from this origin. This has been done abroad, both in Russia and in northern Italy.

More will be said later of its widespread occurrence in nature. Here we are only concerned with commercial sources of the element. One of the strange facts connected with the imports of iodine to this country is that nearly three times as much iodine (711,291 pounds) was imported into this country in 1926, as compared with 1925 (246,474 pounds). In 1927 nearly a million pounds were brought in.

THE ABUSE OF IODINE

The startling statement recently made by a drug journal is that this sudden increase was totally due to the fact that tincture of iodine made with alcohol and iodine, was bought in tremendous amounts by bootleggers for the purpose of recovering the alcohol from it for use in alcoholic beverages.

And what a fine source for a Martini!

Further proof is given by noting that the imports have declined since 1928, when the Prohibition Department got on to the iodine trick.

IODINE OWNS PROPERTIES

Iodine, in spite of its vaporous inclinations—in spite of its tendency to be "up in the air" at the least provocation, is a heavy element, having a specific gravity of 4.66. In appearance it is a bluish black, brittle material, having a metallic luster, and a distinctive, disagreeable odor.

It is not very soluble in water, one part of it dissolving in 2950 parts of water, or about 20 grains to the gallon. Such a solution is

however, not permanent, and particularly so when light is permitted to act upon it. With alcohol and water its solutions are amber colored—with chloroform it shows its true molecular color—violet.

When heated to 114 degrees C. iodine fuses, becomes liquid, and then immediately gathers together its molecular cohorts and begins a large scale migration. Away from the heat its particles go, and only rest when they come to a cooler climate. This is the process of sublimation, and thus is iodine purified.

Its vapors have a beautiful violet color. I do not know whether its emission of these violet radiations has anything to do with its chemical restlessness—certain it is that the wave lengths of light on the violet end of the spectrum are busier chemically than those toward the red end.

Indeed the iodine color scheme is quite diversified. Because of its reactivity with starch, producing as it does a vivid bluish black, it is used as a starch re-agent. A peculiar behavior of this starch iodide is the evanescence of its color. Under the influence of heat the bluish black disappears, only to return again when cooled. Hyposulphite of soda readily dissipates this color, hence its use in removing such stains from starched garments.

With mercury, iodine shows a range of colors from yellow to green to red, depending upon the proportions of the elements. Thus mercurous iodide may be green or yellow, and the mercuric iodide a scarlet red.

One of the most striking of the colored iodides is that of cobalt (cobaltous iodide CoI_2), which in a 15 per cent. aqueous solution becomes red at 10 degrees C., and on rise of temperature exhibits every shade of color from red to olive green.

As I have previously mentioned, iodine is a capricious element. Where it exists in a state of single blessedness it evidences a great unrest—its molecules always on the go—ready at the slightest hint of hot weather, to migrate elsewhere to a cooler climate. Of all the solid bachelor elements, none is so restless as iodine.

Even when wed to another element, iodine rarely honors its vows. In almost every instance the old wanderlust returns. Consider the union of iodine and nitrogen in the form of nitrogen triiodide. Nitrogen, the lazy element, and iodine the volatile, can be united—but not for long. Nitrogen is so fond of freedom—so atomically lazy that it nearly always brands its compounds with a wicked reputation—wicked because of their explosive inclinations—

and explosive because of nitrogen's perennial desire to return to its state of laziness.

Cotton of itself is a sedate vegetable fiber, but let it once be tied to nitrogen the lazy, and oxygen the busy—and it becomes at once the fiery rascal gun cotton. Glycerin the mild, changes its name to dynamite when it weds the nitrate radical.

BANG!!

Now then, what can be expected when iodine the restless, marries this explosion-loving nitrogen! The result of such a union is just what one would expect. The finicky nitrogen tri-iodide, a compound so anxious for explosion that one only has to tickle it with a feather to incite it to violent argument.

This compound nitrogen tri-iodide is the popular metastable chemical system demonstrated to first year students by brave professors who prepare a small quantity of it, and after carefully drying it, cough or sneeze at it, thus setting up sound waves powerful enough to explode this erratic compound.

Even when tied to more domesticated elements than nitrogen, iodine finds bondage a nuisance. There is potassium iodide—a compound so stable under ideal conditions that it can stand without flinching temperatures up to 720 degrees C., where it will go off in a vapor, yet without decomposition. But if the union is sour—that is slightly acid—iodine sneaks to its freedom and the chemical friendship is soon off-color.

Perhaps such a vagabond trait may be a blessing in disguise—for most of the medicinal demands—if not the industrial demands upon iodine, call for it to exercise its properties as a free agent. For it is thus that it seems to operate best in the body cell.

LIFE THE CHEMIST

Yet even the most stable compounds acquire instability when Life must have their molecules. There are chemical changes constantly operating in our moist tissues, operating at low temperatures, and yet producing results that the chemist cannot duplicate under anything like the same conditions.

Consider the production of hydrochloric acid from salt, whereby our gastric utensils are kept to their acid constant. And so, it seems, that Life has a wizard chemistry all its own, and that we have still a lot to learn about its enzymatic, catalytic, electrolytic bag of tricks.

Thus do we humbly approach a consideration of the performances of iodine in the life processes of plant and animal.

Before so doing however, brief consideration will be given to the uses of iodine in the arts and industries, as well as to its uses as an antiseptic.

IODINE IN BUSINESS

Iodine *per se* has little use in the industries, although its compounds find practical application in many fields. A number of important dyestuffs contain it, and are possessed of unusual brilliance.

In photography silver iodide once had a wide use. It was the chemical chosen by Daguerre and Urepce in 1839, in their then startling process known as the "daguerrotype." A silver plate was treated with iodine vapors until a superficial layer of iodide of silver had been formed upon it. After exposure in a camera, the latent image reduced by light to elemental silver, was developed by treatment with mercury vapors which attacked the plate, forming silver amalgam in such places where the light had acted, while in the dark places they left the silver iodide surface unaltered.

LOOKING "DAGGUERS"

The picture was next fixed by washing with a solution of cyanide of potassium, which dissolved away the unaltered silver iodide. Think of the hazards involved in reproducing our grandmother's wedding party—when the poor photographer had to run through a gamut of poisons—from mercury to cyanide. No wonder some of the characters on old fashioned tin types look as if they too had tasted the cyanide.

Nowadays silver bromide is more commonly used in the emulsion, although many special plates and papers of silver iodide are still in use.

A very poisonous compound of iodine with cyanogen, is iodine cyanide. It has some use in taxidermy for preserving insects and butterflies.

The iodides of copper and mercury mixed with water, turn greenish black when they attain to temperatures over 200 degrees C. For this reason they are used to play policemen on rapidly running machinery bearings, to warn of an undue rise in temperature.

So too are they used in detecting the efficiency of sterilizers, autoclaves, etc.

Lead and cadmium iodide have a considerable use as a pigment in bronzing, in mosaic work, in photography.

IODINE—THE ANTISEPTIC

Elemental iodine has a distinct property which it does not always confer upon its compounds, except those which freely dissociate. It is the property of attacking germs. Of course, like most germicides, iodine does not always know how to differentiate between a good germ and a bad germ.

One of the facts so often overlooked in considering germicides is that they are inimical not only to germs but also to other forms of life. Carbolic acid kills the staphylococcus wintering in the carbuncle in the professor's neck—the same chemical will kill the owner of the carbuncle if it is applied inside his neck and not outside of it.

Bichloride of mercury is a fine germicidal agent, and an equally efficient suicidal agent. Arsenic is rough on rats—and just as rough and rough in the same way on the germs of syphilis—but arsenic, you may remember was the poisonous ingredient in Toffana water—that Saint-illumined beauty lotion, which when given internally—never failed in its sanctifying business.

And so it goes with most of our antiseptics and germicides—with the good they do in paralyzing the wicked germ—they interfere with normal living processes. It is a trite though often correct observation—that an operation may be successful though the patient pass on.

Equally correct is it to say that any vicious germ floating in the blood stream can be killed by introducing into the circulation the appropriate poison—only that the germ's host will be quite as abruptly killed.

The ideal germicide is the one that kills invading germs with the least possible damage to the living tissue harboring the germ.

Of course we must remember also, whether we like arithmetic or not, that the dilution factor always enters into the question of germicides. Einstein's theory of relativity may be hitched to the stars, but it touches most every earthly problem too.

So with germicides—so with poisons. The ideal germicide might be defined as one which is not poisonous to animal cells in doses fatal to disease germs—one which is chemically compatible with tissue, one which has a high coefficient of penetration and one which stays just long enough in the tissue to perform its germ-killing ministry. Efforts have been made and are constantly being made to gather together as many as possible of these conditions into the conduct of new antiseptic chemicals.

ANTISEPTIC PARTNERSHIPS

Thus in the new and colorful antiseptic mercurochrome, the highly toxic qualities of mercury and its poor rate of dispersion, due to local coagulation, are compensated for by fluorescein, a dyestuff of high penetration and low toxicity. By the way the latest manifestation of mercurochrome is in the new germ-proof, kiss-proof and soup-proof mercurochrome lip salve.

A similar combination of iodine with fluorescein is already available under the name of iodeosine (tetra-iodo-fluorescein $C_{20}H_8I_4O_5$). It has been used as an indicator, and possesses a color degree of dizzy red, not quite as spectacular however, as that of mercurochrome. So far as I know it has never been suggested as an antiseptic. It is unfortunately insoluble in water, although freely soluble in alcohol. A water-soluble sodium salt of this compound is known as erythrosine, and is a permissible coal tar color for camouflaging food. For all we know then, the bright red pop soda water of circus days may make a better gargle than a beverage.

THE MICROBE KILLER

Let us now consider the status of free iodine as a germicide. Elemental iodine has a phenol coefficient of 4, that is, it is four times as effective as carbolic acid in squelching bad microbes. A 1-1000 solution is sufficient to kill most vegetative forms of bacteria including the staphylococcus, tubercle and typhoid bacillus. Dr. Lambert, reporting in the *Journal of Experimental Medicine* in 1916, states that of all the germicides then tested on germs in the presence of living tissue, a weak solution of iodine was the only one which would kill the bacteria without injuring the tissue cells.

The Research Department of the Philadelphia College of Pharmacy and Science is now working with an isotonic solution of iodine which may to advantage replace the once famous Dakin's solution.

The commonest methods for exhibiting the medicinal as well as the germicidal effects of free iodine are in the form of alcoholic solutions such as the tinctures of iodine and in aqueous solutions, such as Lugol's, where potassium iodide is used to increase the solubility of the iodine.

Tincture of iodine is a 7 per cent. solution of iodine, with 5 per cent. of potassium iodide, in alcohol. The potassium iodide is added in order to permit the tincture to be diluted with water without pre-

cipitating the iodine, and also to render it less likely to form compounds with the alcohol.

As a household antiseptic tincture of iodine has no equal. It combines the therapeutic qualities of iodine, as a counter-irritant and germicide with the local values of the solvent alcohol. It has a high degree of penetration in spite of its theoretical incompatibility with tissue. It is still the surgeon's first choice in rendering sterile the site of operation. When that part of the anatomical landscape has been selected where the surgeon wishes to open his subject, the customary anteslicing performance is a generous dousing with an alcoholic or an ethereal soap solution. After a water wash this is followed by a liberal allowance of tincture of iodine. After a brief delay to permit the iodine to execute every single germ on location, the stain is cleared with alcohol, and the surgeon now gleefully goes to work. That is how much confidence most surgeons have in tincture of iodine.

THE SURGEON'S CHOICE

As a local antiseptic application to fresh wounds and bruises—as a mild counter-irritant, it is not likely that any of the new dye compounds are superior to the century-old alcoholic tincture of iodine. Of course it has some disadvantages—as have all blessings. Its dark disagreement with starched garments, its tendency to concentrate on long standing in unstoppered vials, its bad behavior when too tightly bandaged, and its poisonous nature when taken internally, are all against it.

Yet its stains with starch are readily removed with photographic hypo (sodium thiosulphate). Its tendency to concentrate on long standing in unstoppered vials is easily avoided by keeping it in stoppered vials, and not too long. Its bad behavior when a sore bathed with it is too tightly bandaged can be similarly avoided by withholding the bandage.

So too can its suicidal charms be minimized. As a matter of fact one who chooses tincture of iodine as an easy means to an end, is unesthetic and unreasonable and indelicate, particularly if the last meal was tapioca or rice pudding. As a suicidal implement drowning is quicker, cheaper and cleaner—whereas tincture of iodine is uncompromisingly slow and painful.

But to return to the sensible uses of iodine.

For convenience sake tincture of iodine or other forms of iodine are supplied to the laity in special applicators, such for instance as the iodabs, and the iodamps. Iodabs are short sticks tipped with dry colloidal iodine and intended for local application, after having been first moistened with water.

AN IDEA! Before dismissing the subject of iodine for local application, it has occurred to the writer that the standard book of medicine (the Pharmacopœia) would do well to include a weaker preparation of iodine for domestic use, such a preparation to contain 2 or 3 per cent. of iodine in a mixture of equal parts of alcohol, glycerin and water.

The U. S. P. H. S. has advocated the use by campers and others, of tincture of iodine as a convenient means of sterilizing drinking water. Two drops to a glassful of water, upon five minutes contact, will efficiently sterilize it, and leave no unpleasant taste.

It is the writer's belief that the old fashioned gargle made by adding a teaspoonful of salt, a teaspoonful of vinegar and a teaspoonful of tincture of iodine to a pint of water is still without equal.

Compounds of iodine too, are quite popular as an antiseptic.

"I know a bank where the wild thyme grows"—that oft recurring mechanism which youngsters are sentenced to parse in their grammar classes is only an antiseptic utterance, for wild thyme is now known to contain a germ-killing compound called thymol—which when linked to iodine forms that popular dusting powder known as thymol iodide.

Just beyond the bank where the wild thyme grows is a marsh where as children we used to watch the queer bubbles rise out of the mud, and which we exploded by touching with a match. Now that is marsh gas or methane. Linked to chlorine in a certain proportion this gas produces chloroform, and in another proportion carbon-tetrachloride, the far-famed fire fighter.

But linked to iodine, marsh gas becomes the jaundiced, foul-smelling iodoform. Of course there are many other ways of producing iodoform such for instance as the union of alcohol, alkali and iodine. Now iodoform, commonly called "the hospital smell," is a splendid antiseptic dressing, and only its bad odor prevents its wider use.

A practical joker in medicine has developed a so-called odorless iodoform, which in reality is nothing more than iodoform mixed with

a vanilla like chemical (coumarin), purposed to mask the iodoform odor. Silver iodide in colloidal suspension is also used as a valuable antiseptic.

There are many other medically used compounds of iodine, too numerous to mention.

THE "INSIDE STORY" OF IODINE

The internal uses of iodine and its compounds are not for our consideration here, sufficient for us to state in passing, with reference to iodine, that at some time or another, some compound or another has been used in some plan or another, in the treatment of some form or another of every disease ever known to have oppressed humanity.

In internal medicine such a statement as this is not an exaggeri*sm,* no matter what drug it described. That is the custom—that is the system. Unbelievers in the audience are referred to older issues of the U. S. Dispensatory, where they may find many such panegyrics on the proclivities of unparalleled panaceas, now hardly ever in use.

Iodine when brought in contact with certain vegetable oils, will in time unite with the fatty acid molecule in a very definite way. Its quantitative union with such oils is now used as a factor to determine their identity and purity. Such iodine-oil products are also used as a means of administering iodine internally, their alleged advantage being a slow but steady and thorough iodine liberation and medication.

In addition they have been used as injections in X-ray practice to delineate tissues which when not so injected, do not project their shadow on the plate. Lung pictures and kidney pictures are so taken. A compound of iodine with phenolphthalein (tetraiodophenolphthalein) when injected into the blood will travel unceremoniously through the system until it reaches the gall bladder, where it will sit down to rest its molecules.

IODINE GOES VISITING

If an X-ray picture be taken of the gall bladder under normal conditions, very little if any of its detail may be seen. If, however, a picture be taken while this iodine compound is visiting, the whole outline of that organ may be clearly seen as well as any imperfections it may have.

And here, at last, we approach the interesting part which a very small quantity of iodine plays in our every performance—and to a great degree makes us whatever we are.

YOU AND I!

In 1895 E. Baumann, a German physician, discovered that iodine was one of the important, if not the most important, elemental constituent of the thyroid gland. This gland consists of two maroon colored masses located astride the gastronomic chute above the windpipe, and close to the larynx. Connecting the two lobes which are about two inches long and less than an inch in width, is a narrow isthmus of the same tissue. These lobes appear very much like the flaps of an open purse. The only portion of the normal gland that is readily palpable is this isthmus which

Thyroid Gland.

is attached to the trachea, and may be felt riding under the finger during the act of swallowing.

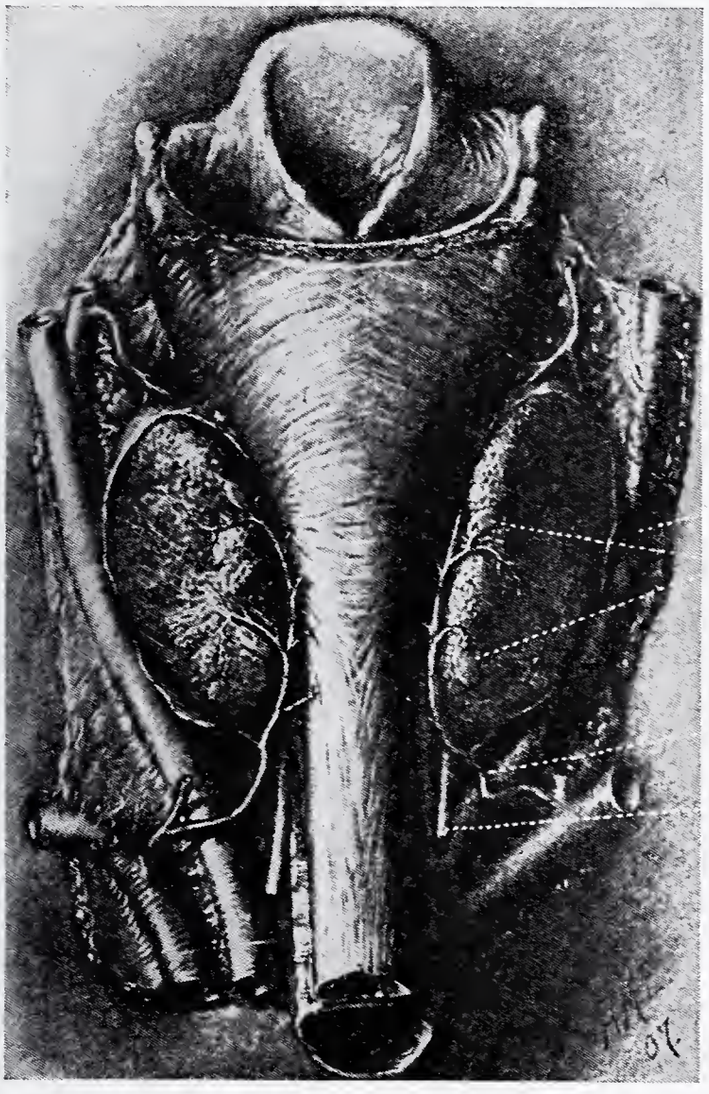
Because of the tendency of this gland to become enlarged and to constitute the prominent deformity known as goiter, it has always attracted a great deal of attention. Normally in man this gland weighs less than an ounce (20-25 gm.), or about 1-2000 or 1-2500 of body weight. This ratio however, is exceeded in infants and in women.

The purpose of the thyroid gland in the body organization seems to be to control the speed of living, in the chemical sense. Physiolo-

gists call this a regulation of the metabolic rate. This it does in some mysterious way by keeping constant the iodine content of our blood stream.

THE SPEED OF LIVING

Thus a thyroid gland which is over-producing accelerates every body function—over-activates the fires wherewith our food, and flesh are burnt away—overworks our thinking mechanism—over-sensitizes our nervous system—over-circulates our blood—and overwhelms our muscles. And everything we do we over-do—and death comes that much sooner.



Thyroid and Parathyroid Glands in Human Throat; the the two small parathyroid glands are imbedded in either thyroid lobe. After Halsted and Evans.

And a thyroid gland which is under-producing slows up the system—under activates the fires wherewith our food and flesh are burnt away, so that the system accumulates poisons—underworks our thinking mechanism—we become dull and drowsy—undermines our

nerves and muscles—and we grow awkward and clumsy—underfeeds the blood and so invites infection. Everything we do we under do—and death comes that much sooner.

Thus in so relatively small a matter as iodine and thyroid functioning—we are impressed with the chemical delicacy of adjustment within us, which makes us the trivial toys of a mite of iodine.

But the remarkable thing today is that with the intelligent use of the thyroid gland from our less fortunate animal brothers and sisters—such as the ox and the sheep, or with the chemical equivalent of the gland in the form of thyroxin and other iodine compounds—many diseases due to thyroid abnormalities may be prevented or even cured.

The metabolic rate of an individual can now be easily studied—and treatment given accordingly.

But as with all such medical discoveries—quacks soon came to abuse them.

GIRTH CONTROL

Listen to the poet—

"Some grow fat with faulty fare,
And some grow fat with laughter."

Now rotundity might have been fashionable once upon a time—but not in these reducing days. Cosmetically and costumically—the fashion of the day calls for the shortest line between two parallel perpendiculars, and mathematically the frail sex has determined upon being reduced to the least common denominator.

The quack soon saw the trick of thyroid and capitalized it. For with its administration to a normal person under lessened diet the body fires burn more brightly—and flesh is broiled away. Surely it will cause a reduction of weight—but it so disturbs other body processes that its use may bring not only a reduction in avoirdupois, but a definite reduction in one's lease on life. Thyroid should not be self administered except under competent medical supervision.

Another recent claim is that baldness is due to a thyroid deficiency. Naturally there were those who at once turned to thyroid medication for cranial reforestation. But again the hazards are too great.

Chatin in 1852 pointed out that goiter was more common in those regions where the soil and water were very low in iodine. Other diseases such as myxedema, and exophthalmic goiter (Grave's disease), were later associated with the thyroid and with iodine.

Cretinism, that dreadful disease of infancy, a disease which once afflicted whole communities is due to a congenital thyroid deficiency. Certain parts of Switzerland, prior to the past quarter century, regularly turned out their quota of cretins. Thirty years ago the cretin was looked upon as a hopeless idiot. Brought into the world as a monstrosity, he failed to develop mentally and physically—and always remained a helpless burden to society. Today by prophylaxis and by treatment, the output of cretins is being annually reduced.

So, too, is the incidence of goiter in spite of its former geographic discrimination. And all of this because the role of iodine in biologic processes is becoming better understood.

THE THYROID IODINE FACTORY

The thyroid gland is present in all vertebrate animals beginning low down in the scale, with the lampreys and complicating its structure and increasing its size as it occurs farther up in the evolutionary scale. In fish the thyroid occurs as small scrubby patches little larger than pin heads—scattered along the important blood vessels. Then in the reptiles it is a little larger and more compact, and still more prominent among the birds and the mammalia. But it is in the primates and in man that it attains to greatest size. Thus it might be said that the thyroid gland is an indicator of evolution.

The farther we are from our early home in the sea the larger the thyroid gland. Now if evolution continues along the same line—a million years from now our thyroid may have become the most important organ in our bodies. And man's appearance may be consequently so changed that instead of being the good-looking creature he thinks he now is—he will have evolved into a pop-eyed, fat-headed, chinless creature—the space between his chin and his collar button having been taken over by his constantly expanding iodine plant.

But that is too far off to worry about. Several things may happen in a million years.

CUM GRANO SALIS

Certain authorities claim that all life was once marine or submarine—that the antecedents of every creature now living, originally like Venus, came from the sea. How they came to own this information is more than I can tell—but that is their story. Just where the sea secured its life is a question they have not ventured to answer.

One of the slender threads wherewith they join their arguments is in the remarkable comparison which they make between animal blood and sea water. When blood is permitted to coagulate the clear, rather colorless serum or plasma which separates, has, exclusive of its protein content, a composition very like that of sea water. It contains so much sodium chloride—so much phosphates—and carbonates—and so much combined iodine—in a ratio similar to that of sea water.

The contention is that whereas we were once limpid jellyfish that floated lazily on the dark primeval seas—we are now so evolved and involved that a share of the sea floats diligently within us, with an ebb and flow in every heart beat.

Certain we are that life in us could not get along without the sea elements that race in our blood stream. Lacking the little salt that parades its molecules constantly—through sleep and waking periods in us—no longer would life reside—nor indeed would life stay with us without our mite of iodine.

And what a mite it is. Listen. The high tide of iodine in the blood is about one grain of iodine to ten million grains of blood, or less than a hundredth of a grain to the entire circulation. The reservoir of iodine in the body, namely the thyroid gland, only holds a third of a grain (about 25 milligrams) and in order to keep this reservoir full one only has to consume per day, in his food or drink, less than a thousandth of a grain of iodine. No wonder some folks believe in homœopathy. It seems the Great Designer did!

IODINE DAY ON FRIDAY

I do not know the canons of the Church of Rome nor its history, well enough to identify the origin of the custom of sea-food for Friday. In any event it is a good custom, for though Friday euphoniously admits of a fry—fried fish will furnish our weekly requirements of iodine far better than anything else we might fry, or try. And so, much like the Mosaic indictment of pork† whereby our Jewish friends are denied the gastronomic joys of a ripe red ham (unless they call it pickled salmon) the Friday fish day may have had a dietary hygienic value.

I mentioned 1895 as the year of the discovery of iodine in the thyroid gland. The form in which iodine is present in the gland was

†Hog meat particularly in the Orient and near-Orient harbors a parasite which can infest and infect the human system (Trichinosis) producing a vicious disease. Moses was not a bacteriologist, but he had a fine understanding of sanitation and public health measures.

reported by the American Kendall as late as 1916, and named by him Thyroxine. It is a crystalline compound containing 65 per cent. of iodine. In 1926 Harrington of London more accurately described it, and in 1927 duplicated it by synthesis, in his chemical laboratory. So that you may have some idea of the complexity of Harrington's duplicating job, here is the full chemical Christian name of the substance: beta-tetra-iodo (3, 5, 3^1, 5^1)-4-(4^1-hydroxy-phenoxy)-phenyl-alpha-amino-propionic acid.

So it seems evident to us that intimate knowledge of the role of iodine in life is quite modern.

But listen, while London was yet a muddy fen and Rome a rambling village—China had a mind of her own—and a culture of her own. When the civilizations of Athens and Rome were yet in knee pants—Cathay had spun her cycles.

CHINA KNEW

Four thousand years ago the Chinese had guessed that goiter was a disease related to diet—that it mostly attacked people who lived away from the sea—that it yielded sometimes to treatment with sea medicaments—salt of the sea—sponge from the sea—sea-weeds and coral. Yes, indeed, the art of the ancients was in knowing how—not why.

Thyroxin-Crystal of Kendall's own preparation.

Later Dioscorides, a Greek physician, and author of a treatise on Materia Medica, recommends the use of sponge to "check tumors"—and if we assume that by tumors he meant goiters, we have to admit that he "knew his sponges." The Syriac Book of Medicines (200-300 A. D.) directs "burn a sponge in the fire, crush it in wine and administer as a draught."

And so was burnt sponge used in medicine for centuries, only to be displaced in modern times by iodine and its compounds.

Indeed the first Pharmacopœia of the United States, published in Boston in 1820, gave it a place though it was deleted in the next revision. So too was a variety of burnt sea weed included.

Today burnt sponge and bladder-wrack are still used by the eclectic physicians, who believe that these natural products in contradistinction to iodine or its definite artificial compounds, contain a structural "something" that must be very different from pure iodine or a single iodine compound. And they may be right.

℞ SPONGE

A strange fact regarding sponge is its property while alive of abstracting iodine from sea water. In some tropical species of sponge the iodine content of sponge ash may run as high as 8 to 14 per cent.. while seaweed ash from which some commercial iodine is obtained rarely exceeds 1.5 per cent. Since it is assumed that all the iodine in sponge comes from sea water and sea organisms, it has been calculated that one pound of sponge contains the total iodine content of twenty thousand tons of sea water. Rather a remarkable figure.

Most all sea organisms, plants and animals too are rich in iodine. As previously mentioned much of the iodine of commerce is obtained from such sources. Even the humble oyster, whether brought up in well-aired beds or not, contains his share of iodine.

Sea water contains about 1-300th of a grain of iodine to each gallon (0.05 mgm. per Liter.). It is of interest in passing to note that the Great Salt Lake of Utah contains but a little more iodine (about 1-200th grain to the gallon), whereas it contains five times as much salt.

Of interest too is the fact that we have enough iodine in the sea to last our children for a long, long time. Practically all of the iodine in this planet is in the sea and a dabbler in useless arithmetic has figured that it amounts to a few pounds short of sixty billion metric tons, which antiseptically leaves us nothing to worry about.

Plants and animals which now reside in the sea are not alone in their iodine content. For land plants, too, in varying amounts, contain this element. The sugar beet, for instance, contains more than a trace of it, and recently special fertilizers containing small amounts of iodine have been recommended for this vegetable. Watercress too, contains considerable iodine, and so do many other plants.

IODINE—LANDSMAN

It is assumed, however, that the presence of iodine in plants and in the lower forms of animal life may be incidental to its presence in the soil, and in certain inland waters. In rock formations iodine is frequently associated with the minerals, particularly copper, silver and mercury. Soil and sod, too, contain its compounds, though in very small and variable amounts. The volatility of the element suggests its presence in small amounts in the atmosphere, too. Generally speaking the soil of coastal regions is higher in iodine content than that of inland regions.

It has been a well-intentioned assumption that iodine, like its cousin chlorine, is wafted inland in the form of spray from the halogen rich oceans, and that these elements are thus literally sprayed over the land, finding their way to soil and sod and running waters. And this of course, explains why iodine hugs the coast line.

As with most assumptions of this nature, the truth is only partially met. However, it has been recently pointed out that while the salt spray theory of iodine distribution seems to have gained general acceptance, the Atlantic Ocean contains only twenty-three parts per billion of iodine, and *five or six parts per billion* in the water of streams cannot come solely from spray unless the waters contain a like proportion of the other salts of the sea, which they do not. As for foods grown on land, in South Carolina there is a tendency to higher iodine content in that part of the state which is more distant from the coast and nearer the Blue Ridge of the Appalachian Mountains. It has been suggested, therefore, that the main source of iodine in the vegetation of such regions lies in the disintegration of the granite rocks, and that this has been supplemented by the liberal use of commercial fertilizers over a period of years. This supply of iodine is being conserved by the return of vegetable matter and animal wastes to the soil.

CAROLINA MOON

South Carolina has capitalized the alleged heavy iodine content of her vegetables by ridiculously adding the word IODINE to her automobile license plates, and by circulating a silly slogan—

A potato a day
Keeps goiter away.

Which shows how the low surface tension of ignorance can make even the so-called authorities run away from sound sense. The "Carolina Moon" *will out*.

Yet much has been constructively done to awaken the world to the realization of the fact that iodine deficiency in food is the commonest cause of goiter and other diseases. The resulting world-wide movement to insure the presence of sufficient iodine in the diet to prevent these dreaded diseases is one of the greatest prevention measures undertaken by man in the interest of good health. Yet the wholesale methods used have not been without danger for there are types of gland affections which are radically aggravated by iodine medication, and are only amenable to surgical care.

IODOPHOBIA

Had we more time at our command we might have dwelt more fully upon these prophylactic measures —such for instance as the now tabooed charging of drinking water with iodides, or the general use of iodized salt. Iodized salt, containing from 0.02 to 0.025 per cent. of iodine in the form of iodides, is now available in the stores. But we repeat that with community medication of this kind it must not be overlooked that harm can come from feeding iodine to individuals who already have enough or too much, just for the sake of catching those who have too little. It is a matter always of individual treatment. Nor must we overlook the danger of inducing in the individual through over-dosage that uncomfortable chemical disease, iodism. Indeed it is not always a matter of over-dosage for to iodine as well as to most everything there are persons who display idiosyncrasy.

Then too, we might have discussed the role which the thyroid and other glands played in the differentiation of the human family, insofar as color and race are concerned—for once, so it is said, all men were black. The change in our pigment, in our physique and physiology has been largely due to the refined alchemy of those little internal laboratories which we call glands.

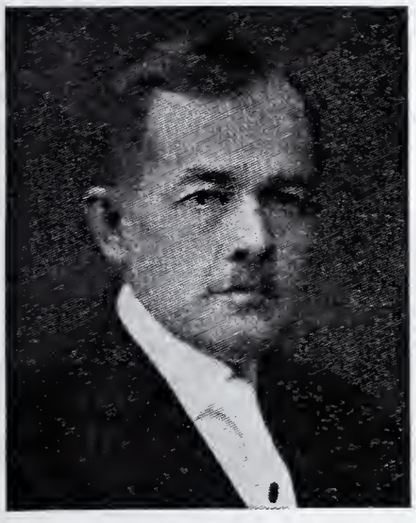
Theirs is the verdict of our personality. They are the architects of our qualities and the arbiters of our destinies. If ever man shall know just how human nature may through their use be bettered—or be controlled—then he will have reached Utopia.

SEVENTY YEARS OF PETROLEUM

By Freeman P. Stroup, Ph. M.

Professor of General Chemistry, Philadelphia College of Pharmacy and Science

PETROLEUM (petra=rock, oleum=oil), in some of its many varieties, has been known certainly for many centuries, and there is reason to believe that it, or a fraction obtained from it, may have been the substance referred to in certain very ancient bits of literature the English translation of which uses terms which often mean something else nowadays. For instance:



Freeman P. Stroup, Ph. M.

In Genesis we read that God instructed Noah to build an ark, and, among other things, to "pitch it within and without." The manner in which that famous vessel "weathered the storm" indicates that Noah followed "specifications" to the letter, and it is quite possible that the "pitch" was of mineral origin.

ANOTHER ARK In Exodus we read of the construction of another "ark" (this time a very small one) by the mother of the infant Moses, who, to make it water tight, "daubed it with slime and pitch." While the "pitch" may have been of vegetable origin, it is quite possible that it was of mineral origin. It is significant that in modern times there has been a considerable production of petroleum in the Nile Valley. Besides, Egyptian mummies often show evidence of the use of petroleum pitch in their preservation.

Later on we find Job wishing for the good old times "when the rock poured me out rivers of oil." The modern once-owner of a good "oil production" (oil country parlance for good oil-producing property) knows how to sympathize with the old patriarch in his lament; as does also the man who has spent the greater part of his life working about oil wells with the hope that some day he might be able to "strike oil" and acquire the competency that would enable him to "take things easy" for the remainder of his days.

FIRE WORSHIPPERS

Agrigentum, in Sicily, burned oil in rude vessels prior to the Christian era, and Genoa and Parma, in Italy, lighted their streets for two centuries with burning oil, the evidence in both cases being that the oil was of mineral origin. It has been thought that the oil poured over the Christian martyrs in Rome and elsewhere to convert them into human torches was a petroleum oil. The ancient "Fire Worshippers" paid obeisance to burning fountains of oil and gas, undoubtedly of mineral origin. An oil fountain in the Ionian Islands is said to have produced oil for 2000 years. Centuries ago the Assyrians gathered oil from seepage basins near Bagdad. A few years ago a well drilled in the same vicinity produced oil for a season at the rate of 90,000 barrels a day.

In the United States of America the Seneca Indians knew oil and used it for various purposes, and books of travel of 300 years ago mention it. In western Pennsylvania, particularly, it was found floating on the waters of some springs and the streams fed by them, and owners of salt wells were often put to much inconvenience by its presence in the waters of the wells.

Of "The American Well," drilled in Kentucky in 1829, Nile's Register says: "Some months since, in the act of boring for salt water . . . a vein of pure oil was struck, from which it is almost incredible what quantities of the substance issued. The discharges were by flood, at intervals of from two to five minutes, at each flood vomiting forth many barrels of pure oil." The floods are said to have continued for three to four weeks, and thereafter the well flowed a steady stream of thousands of gallons daily for more than thirty years. The oil was sold largely for medicinal purposes in bottles labeled "The American Medicinal Oil, Burkesville, Ky."

ROCK OIL

About 1849, S. M. Kier, a Pittsburgh druggist, noticed a striking similarity between this "American Medicinal Oil," which had been prescribed for his wife, and petroleum obtained by his father from a 500-foot brine well at Tarentum, Pa. Action followed quickly and soon the "armamentarium of the physician" was increased by a "wonderful new remedy": "Kier's Petroleum or Rock Oil, a Natural Remedy," etc., etc., etc.,

"The healthful balm from nature's spring
The bloom of health and life to man will bring,
As from her depths the magic liquid flows
To calm our sufferings and assuage our woes."

All of this and a lot more piffle for fifty cents a half-pint bottle. The sales averaged 2000 bottles a day—not a bad business when the bottles and labels cost only a few cents each, and the contents between three and four cents. The production exceeded sales, so Kier conceived of the idea of fractionally distilling some of the oil and selling the lighter portion as "Carbon Oil" for burning in lamps (thus displacing to some extent a similar product made from coal and known as "Coal Oil"), and selling the heavier portion to a factory at Cooperstown for cleansing wool.

THE DRAKE WELL

The petroleum industry proper is only a few months over seventy years old. In 1857 Colonel Edwin L. Drake, formerly a railroad conductor living in New Haven, Conn., took a contract to drill a well for oil on Watson's Flats, about a mile below Titusville, Pa., on the banks of Oil Creek. It took him quite a while to get to the scene of his proposed operations, but he finally landed in Titusville, and was able to secure board and lodgings for himself, his wife and two children, and feed and stabling for his horse, all for $6.50 a week. He encountered many difficulties but surmounted them all and finally, in August, 1859, had the well drilled to a depth of sixty-nine and one-half feet, at which depth he "struck oil," and thereby initiated a period of excitement among fortune hunters that likely has never been eclipsed by that occasioned by the discovery of gold, silver or diamonds in any new locality. The "Drake Well" produced about 1800 barrels of oil in the first four months of its existence, most of it selling readily at twenty to twenty-four dollars a barrel of forty gallons. The yield went down rapidly thereafter, other wells were "brought in," causing the price of oil to slump terribly, and the "Drake Well" was abandoned. The site of the well is marked today by a large boulder on which has been placed a bronze tablet suitably inscribed to indicate this as the birthplace of the American petroleum industry. It is interesting to note here that petroleum has been produced from wells drilled in the vicinity of the "Drake Well" almost continuously during the past seventy years, but from greater depths.

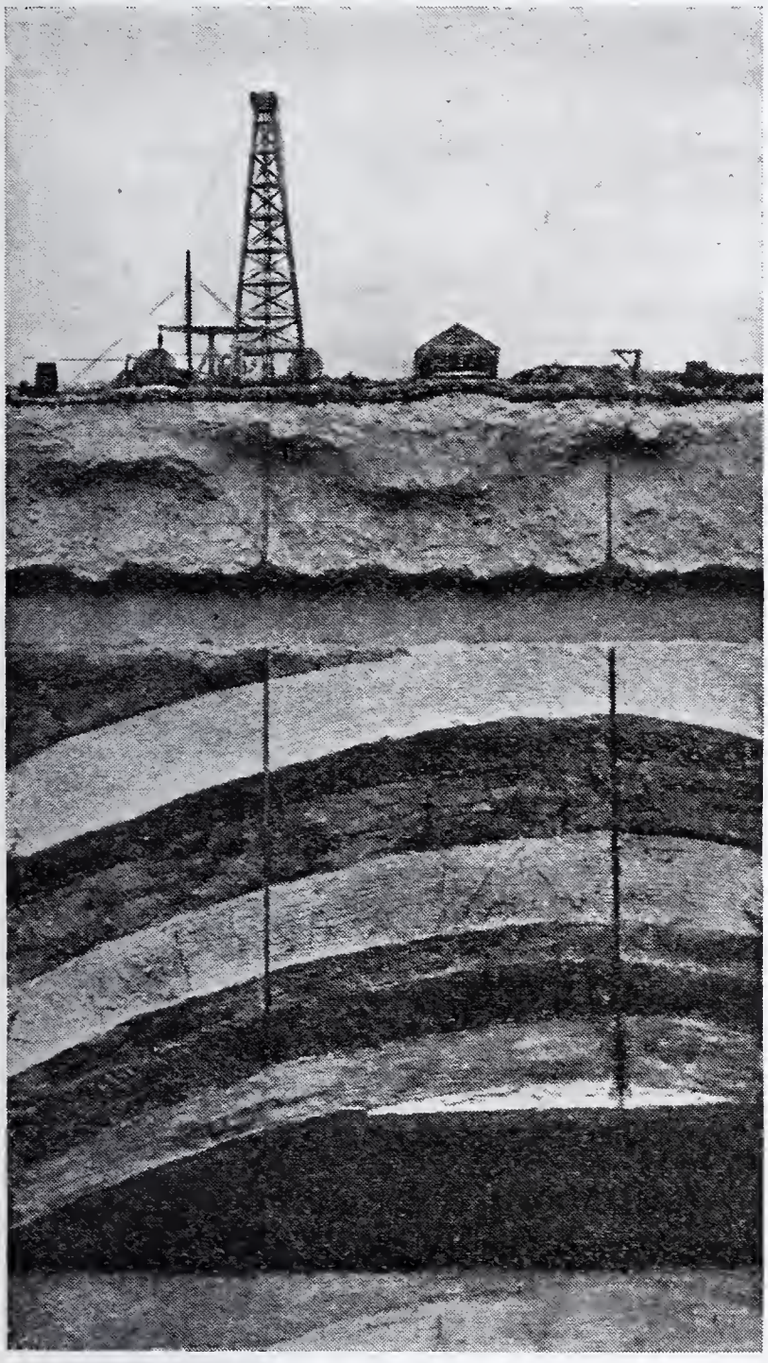
As has been generally the case following the discovery of a valuable mineral in any locality, the land nearest the "Drake Well" was speedily acquired by purchase or lease and other wells drilled thereon, so that soon the valley, both above and below the well, for several miles, became a very busy section of the state. At first, everybody seemed to think that oil was to be found only under the floor of the valley, and the first man to venture up the side of a hill

was thought to be crazy. However, oil was obtained from the side hill wells in as large quantities as from the wells on "the flats" (only at greater depths), and then the seekers after wealth not only climbed the hills but actually "went over the top" with their drilling operations, "wild-catting" out in different directions; so that, in a few years, a number of so-called "fields" were opened which were very productive of "the oleaginous fluid." Some of these "petered out" in less than a year, some lasted for several years, and some have been productive on a very small scale ever since. Many of them are only a memory to the very few survivors of that period, not a stick or a stone being left to indicate that they had at one time been scenes of human activities of the wholesome kind as well as scenes of the lowest forms of human depravity. To mention only one of them, Pithole, Venango County, at one time in its meteoric career did the third largest post office business in the state; today there is nothing there to indicate that it had ever been anything but a few fields of poor farming land.

YIELDS OF WELLS

The "Drake Well" production at first was about twenty barrels a day, but within a few years wells were drilled which produced upwards of 800 barrels a day, and a few so-called "gushers" had an initial production of 1500 to 2000 barrels. With the manufacture of heavier and larger tools came the occasional opening of very much heavier producers. Individual wells in California, Oklahoma, Texas, Mexico, Russia, with productions ranging from 5000 to 20,000 barrels a day have been not uncommon. Two Mexican wells, the Cerro Azul No. 4 and the Casiano No. 7, stand out as giants among oil wells, the former being estimated to have "spouted" 260,858 barrels of oil in the first twenty-four hours after it began to flow, and the latter being estimated to have produced more than 59,000,000 barrels in its lifetime. The annual production in the United States prior to 1859 was estimated at fifty barrels, in 1863 it was 40,816 barrels, in 1901 it was over 85,000,000, in 1921 it was over 440,000,000, in 1924 it was 713,940,000. The total production in the United States to 1925 was 5,300,000,000 barrels, and it was estimated at that time that we still have 26,000,000,000 barrels recoverable by "present" methods, at which time it was stated that the methods then in use produced only about 20 per cent. of the amount available in any one locality. It seems quite apparent that there is plenty of "drink" in sight for the "old flivver," at least during our "day and generation," even though the consumption of motor fuel in this country during 1929 was

365,000,000 barrels, and the consumption of kerosene, lubricants, petrolatums and paraffins (all obtained from petroleum) ran up into the hundreds of millions of barrels.



Cross Section Model of Petroleum Well.

Geographically, the known oil-producing sections of the world are widely distributed, and are to be found on every one of the continents. On the North American continent nearly every state in the United States west of the Appalachian Mountains has its oil fields, the chief producers being California, Oklahoma, Texas, Arkansas and Louisiana, Pennsylvania and West Virginia; western Canada and Northern Mexico are noted for their oil production. The South American production has been chiefly from countries bordering on the Caribbean Sea and on the Pacific Ocean. Central Europe has produced some oil, but by far the largest production has been in that part of Russian bordering on the Black Sea and the Caspian Sea. In Asia the largest production has been from countries in the southern part—Persia, India, Indo-China and the East Indian Islands. In Africa the chief fields have been located along the northern countries and Egypt. Some oil has been produced in Australia.

Geologically, petroleum has been obtained from a great variety of strata: from shales in some parts of the United States, in Scot-

land, Newfoundland, Canada, Australia; from porous sandstones in Pennsylvania, West Virginia, Southeast Ohio, Kansas, Kentucky; from pebbly sandstones in Northern Ohio; from Trenton limestone in Indiana; from loose-grained quartz in Texas; from black shale in Colorado. While there is evidence that it is sometimes filling cavities in the rocky strata, the most of the oil simply saturates the rock, much as water may saturate a sponge, piece of wood or other porous material; and this explains the assumption that we are getting out of the earth at any one place only about 20 per cent. of the oil that is there—capillarity holds the rest.

The depth to which wells have been drilled has varied from a few feet to over 8000 feet, dependent upon the locality and the nature of the surface. Several wells only a fraction of a mile apart may differ quite a number of hundred feet in depth, according as one is situated in a valley and the other on a hill.

The cost of drilling is primarily dependent upon the depth—one of 600 or 700 feet in depth being capable of being finished in a week or ten days, while one 5000 feet in depth may take a year for completion. The former may cost only a few hundred dollars, while that latter may cost $50,000 or more. Wells in the neighborhood or Los Angeles are said to cost from $40,000 upwards each.

The life of wells varies greatly. Some have flowed strongly for a few days and then "played out" completely; others, after a few days or weeks of strong flow, have settled down to be "steady pumpers" of moderate yield for a considerable number of years; very occasionally one is found that has been producing at least a little oil for more than fifty years. There is said to be one at Pleasantville, Pa., only a few miles from the "Drake Well," that has been producing constantly since 1867. The speaker knows personally of a number of fields that have furnished nice incomes to their owners for a half century; not, however, from the first wells drilled, for wells in these particular sections often cease producing after some years, but other ones drilled in the immediate vicinity often start out well and remain good producers for a dozen years or more.

DRILLING A WELL

The drilling of an oil well is accomplished by one or the other of two general methods—"churn drilling" or "rotary drilling." The former is the older of the two and is still largely used. It is called "churn drilling" because of the up and down motion of the tools which is that of the old-fashioned dasher churn used in making butter from cream. The essential parts of a "string of tools" for

this process are a "rope socket" (an iron device fastened to the end of the rope "drilling cable"), and capable of being screwed to the end of the "auger stem" (a long cylindrical steel bar to make possible the drilling of a straight hole and to give weight to the drilling "bit" screwed to its lower end). The "bit" is a relatively short steel bar, the lower end of which is somewhat flattened, wider than the body of the rest of the implement, and hammered out to a blunt edge resembling that of the "business end" of a stonemason's chisel. Drilling is accomplished by alternately raising the tools fifteen to twenty-four inches from the bottom of the hole and allowing them to drop, rotating the tools so that the bit hits the rock at different angles and crushes it. If there is no water in the hole naturally, enough is put in from time to time to make a thin mixture with the drillings that will not interfere materially with the hitting of the bit on the bottom of the hole. From time to time the tools have to be withdrawn to permit of the sharpening ("dressing") of the bit, and also to permit of the removal of the mixture of water and drillings from the hole. The "dressing" of the bit is accomplished by heating the end in a forge to a reddish-white heat and then by means of heavy hammers ("sledges") drawing out the metal to the desired degree of sharpness, then "tempering" the edge by standing the bit on end in a vessel of water. The drillings are removed from the hole by "running" the "sand pump" or "bailer," both of which are long cylindrical vessels attached to a rope ("sand line") operated from a reel run by friction against the "band wheel." The "sand pump" (or "bailer") is allowed to run down into the hole where it fills with the drillings, a suitable valve closes to keep the drillings in the implement, and it is then withdrawn from the hole and emptied. It is "run" as often as may be necessary to remove the most of the drillings, the tools are replaced and drilling resumed.

The surface apparatus needed to handle the tools constitutes what is known as a "drilling rig" (generally called "rig"), the main features of which are:

a. The "derrick," a square tower made of two-inch planks ten to twelve inches wide spiked together at right angles for the corners, the corners tied together at intervals of eight to nine feet by "girths," and the spaces between "girths" spanned by diagonal "braces." The "standard derrick," still largely used, is set on a frame twenty feet square made of heavy timbers ("sills") and covered with planking to constitute a "derrick floor." The top of the "derrick" supports the "crown block" which in turn holds the "crown pulley" over which

runs the "drilling cable." Near the top is another "block" holding the pulley over which runs the "sand line." These "derricks" are seventy-two to seventy-four feet high, and are necessary for the handling of the modern "strings of tools" which are upwards of sixty feet in length. In one side of the "derrick" (at the rear end of the whole outfit) are mounted the "bull wheels," a heavy reel holding the unused portion of the "drilling cable" and used for raising and lowering the tools, for which purpose the "cable" goes up the inside of the "derrick" over the "crown pulley" and down the center of the "derrick" to the hole. The reel is operated by two large wheels, one of which is a form of pulley operated by a heavy endless cable from a corresponding pulley on the "band wheel," and the other of which, together with an adjustable steel strap that surrounds its periphery, constitutes a "brake," useful particularly when the tools are "run back" into the hole.

b. The "band wheel," a large upright-set wooden wheel set with its shaft eighteen to twenty-two feet from the drill hole and directly opposite the "bull wheels." It is also fitted with the pulley necessary to carry the cable which transmits power to the "bull wheels," and to one end of its shaft is attached the "crank" which is needed to give, by means of the "pitman," the oscillatory motion to

c. The "walking beam," a beam of wood eighteen to twenty-two feet in length, supported at its center by an upright post called "the samson post." The "beam" end above the "hole" is fitted with a "temper screw," a device by which the "cable" can be gripped at any desired point, and also by which the tools may be gradually lowered as drilling proceeds.

Power is supplied to the outfit by means of an endless flat belt from some kind of an engine, usually operated by steam. At one time the engine was often mounted on the boiler, and this unit outfit was not so heavy that it could not be easily moved from one location to another by means of a team of four horses.

Because of the growing scarcity, and consequent high price, of wood, steel "derricks" have replaced wooden ones in many oil fields, and in "shallow territory" so-called "portable rigs," such as are often used for the drilling of "artesian" water wells, have replaced the more expensive "standard rigs."

"Rotary drilling" is practiced in "deep territory," as in the California fields near Los Angeles and Long Beach. As the name implies, the drill is kept in rotary motion and the rock is worn away by attrition. The drill is attached to the bottom of a "string" of pipe

to which a rotary motion is imparted by suitable apparatus at the base of the "derrick." No "beam" is necessary in this style of drilling, but the "derrick" is needed to handle the pipe and drills. It is usually higher than the derricks used in "churn drilling." "Drawing the tools" is very much less frequently done, this constituting a decided saving in time and power.

In the early days of the oil industry in Pennsylvania some wells were literally "kicked down," that is, the rope holding the tools was fastened to the small end of a strong wooden pole the large end of which was anchored in the ground, and near this end the pole rested across a support somewhat in the manner as a fisherman sometimes "sets" his pole in a boat or along the shore. The driller fitted the rope with a device on which he could apply pressure with his foot after the spring of the pole had raised the tools from the bottom of the well. Of course the tools were very light as compared with the weight of those used with regular riggings. Only very shallow wells could be drilled by this method.

Too much water in the hole hampers the drilling operations, so it has been the custom almost from the first to "case off" any water that came in from any stratum. This was effected by drilling to some distance below where the water was first encountered, then putting in a "string of casing" (heavy pipe) somewhat smaller in diameter than the diameter of the hole, making a tight joint with the casing and the bottom part of the hole by use of a leather bag filled with flaxseed tied firmly to the bottom of the casing, or a leather cup fastened to the bottom of the casing, and filling in the space around the outside of the casing with drillings (cement nowadays) to some distance above the bottom. The water swelled the leather and flaxseed, or leather alone, and made a tight joint. Drilling was resumed with a smaller bit, small enough to go down the inside of the casing. When a well is permanently abandoned for any reason it is the general custom (generally required by law) to "plug off the water" by putting a wooden plug in the smaller hole below the end of the casing and running in cement or other filling material. The casing can then be removed without neighboring wells suffering damage by being "watered out" because of the water coming into the oil-bearing "sand" from the abandoned well.

In localities where wells are apt to flow when the oil-bearing stratum is tapped the casing may be fitted with an "oil saver," a device which permits the diversion of the flow to a suitable reservoir, even if the flow should begin before the tools can be taken from the

hole. In localities which produce both oil and natural gas the casing may be fitted with a "casing head," a device by which the gas coming up from the depths between the inner wall of the casing and the outer wall of the "tubing" can be diverted into suitable pipes leading away from the well for utilization as fuel or for other purposes.

Most "producing" wells do not flow, and are known as "pumpers." Such wells are drilled from seventy-five to 100 feet or more deeper than the level of the oil-bearing "sand," this last extra depth constituting a "pocket" in which oil can accumulate between pumping periods ("heads"), which may be a few hours apart—or even days apart where the production is very light. The pumping apparatus consists of a "string of tubing" (iron pipe ranging from about one and one-half inches in diameter upwards, depending upon the amount of liquid it will have to accommodate) extending to near the bottom of the well, inside of which works a "string of rods" (formerly wood, now generally steel fastened together by screw joints) fitted at the lower end with a set of lift valves moving in a "working barrel" fitted to the bottom end of the "tubing." Of course the upper end of the "tubing" has a side pipe ("lead pipe") leading away to some kind of vessel, which is often an old barrel or small iron tank standing on the derrick floor, from which another pipe leads away to a larger tank ("the receiving tank") for storage until sold. If the well pumps both water and oil these are usually separated in the small receiver on the derrick floor, by having the tank tapped near the bottom and the short leg of an ell device (of two lengths of pipe connected by an "ell") inserted, the open end of the longer leg of the "ell" being raised to without a few inches of the level of the pipe which leads off to the storage tank. Sometimes the "ell" is put inside the tank with the longer leg reaching near the bottom and the short leg piercing the wall of the tank below the oil outlet pipe. In either case the water is removed through the "ell" device while the oil, being lighter than water, floats on the surface of the water and off through the oil outlet pipe. At no time is there more than a few inches of oil level in the small tank.

INCREASING PRODUCTION

The diameters of the first oil wells were only about four inches, and while there has been an increase of diameter since that time an oil well is still a rather small "hole in the ground," and thus a rather more risky place into which to trust one's money than is the gold mine which is largely a dug shaft. Of course, because of the fluidity

of oil, it may find its way into a well through seepage though the well may not have been drilled into the exact spot where the bulk of the oil lies. Early in the history of the industry someone conceived of the idea of enlarging the hole at the oil-bearing level by blasting with explosives. The first "torpedo" is said to have been a three-foot length of two-inch copper tube filled with rifle powder and exploded with a fuse. This was in 1860. In 1865 five pounds of powder in an earthenware bottle on the end of a pipe was fired by dropping a red-hot rod of iron through the pipe. E. L. Roberts got a patent on the idea. Later he substituted nitroglycerin for the powder with better results. He and others to whom he issued licenses charged exorbitant prices for "torpedoing" wells, so there sprang up what were known as "moonlighters," men who used the idea without paying royalties, and generally "shot" the wells at night. The explosive, on which there was no patent, was manufactured at so-called small "factories" in more or less isolated places here and there in the oil country, sold in square tin cans holding about a gallon, and transported to the place where it was to be used, generally over very bad roads, by means of any kind of vehicle that was available. Accidents were frequent and it was no uncommon thing to see accounts of such accidents in local newspapers stating that "all that could be found of the driver was gathered up and put into a cigar box for burial." Indeed, it has been suggested that some newspapers kept this line or some similar one set up in type for instant use. The "shooters" would not take the risk of either arrest or accident by taking the cans back to the "factory," so they were usually secreted under rock piles, in the hollow stumps of trees, or sometimes just taken out into the neighboring woods and left there. Numerous casualties resulted from the attempted use of some of these cans for one purpose or another on the part of persons who were not familiar with what their previous use had been. Enough of the explosive adhered to the inside of every one of these cans to make it capable of seriously maiming, or even killing, any person who was within a few feet of it when, by any means, it was exploded. Disappointed hunters coming home with an "empty game bag" sometimes amused themselves by setting one or more of the cans up on a stump or stone pile and emptying their "muzzle loaders" at it or them, with sometimes very surprising results. Two or three quarts of nitroglycerin constituted a "shot" at first; 150 quarts is not considered as a "very heavy charge" now. The explosive is put into long tinned iron "shells," these fitted with detonators ("caps") and lowered into the

well, and "anchored" where the "log" of the drillers indicates the oil-bearing "sand" was found. The "anchoring" may be accomplished by fitting to the bottom of the "shell" a length of tinned iron tubing corresponding in length to the distance from the "sand" to the bottom of the well, or by measuring a length of wire or stout rope to correspond to the distance from the surface to the "sand" and suspending the "shell" on that. The "cap" is exploded by dropping a piece of iron onto it, or by the use of electricity, or by dropping a "squib" (a can containing a few ounces of the explosive) fired by a slow-burning fuse into the hole. To make the charge most effective oil or water is run into the hole in sufficient quantities to produce a layer several hundred feet thick over the "shell." The firing of the "torpedo" is evidenced by a deep "boom" within the earth, followed shortly by a fountain of oil, or water, or both, coming from the top of the "hole," rising sometimes to a height of 150 feet in a solid stream and then bursting into spray which showers the rig and a goodly portion of the surrounding neighborhood. In the case of shallow wells there is also a lot of rock debris in the fountain, pieces as large as hen's eggs sometimes being thrown out. It does not seem likely that any very large holes are blasted out of the sides of the well, but the rock is probably very much shattered and opened up; for, if the well has produced any oil "natural" (without "shooting") it generally has its production materially increased by "shooting." And even if a well appears "dry" after being drilled to the depth where other wells in the neighborhood have yielded oil, the owner will not generally "abandon the well" without taking "one more chance" at finding oil by ordering some "shooter" to "give her a shot." Frequently has he been well rewarded for his faith (or hope) by having a "good well" "blown in," and very occasionally has a "duster" been converted into a "spouter" by the firing of a well-placed "shot."

REJUVENATING OLD WELLS

The petroleum found in Pennsylvania is chiefly a mixture of saturated hydrocarbons, and the so-called "second-sand oil" contains a considerable percentage of what is called paraffine when it is properly purified. The theory was prevalent in "second-sand territory" that this paraffine deposited out of the oil in the wells and gummed up the rock so much that oil could not come through into the wells. Various treatments besides "light shots" were used by different "operators." Some emptied a number of barrels of gasoline into a well, left it to dissolve away the

paraffine, and, after several days, began pumping the well again. Gasoline was worth very little in those days. Others extended one-inch pipe into the bottom of the well and forced through it "live steam" to melt the paraffine or force its solution in the hot oil. Another method used was that of attaching a "gas pump" to the casing head and operating it to reduce the pressure within the well so that rock pressure would force the oil in. A practice that has caused certain old-time "oil fields" (the Bradford, Pa., field is a conspicuous example) to "stage a comeback" within recent years is that of using certain wells in a district for pumping and a certain number of others in the same district through which to force water down into and through the "sand" to displace the oil. Sometimes the holdings of a single "operator" are large enough to pay him to drill both groups of wells; oftener "operators" on adjoining "farms" "pool their issues" and drill the water wells along the line dividing their holdings and the oil wells at determined distances farther away from the line. It appears that this practice is one good way to get some of the 80 per cent. of oil that is said to be left in the earth by the old-time methods. The Federal Government is trying to find other ways to accomplish the same result, particularly as the demand for petroleum products is said to have increased 650 per cent. in recent years, while the production has increased only about 150 per cent.

STORAGE

As has been previously stated, the oil from pumping wells is usually pumped into small receivers standing on the derrick floor or nearby, where the water, if any, is separated; it is then run into a larger tank formerly made of wood but often made of iron today, which tank may hold 100 barrels, 250 barrels, or very much more, depending upon the size of the "production" of the group of wells belonging to any one particular holding. This larger tank is commonly called "the receiving tank" and is used for storage until such time as the owner sells his oil, when a "gauger" comes and measures the depth of the oil in the tank, allows it to flow into the "line" of the company who has purchased the oil, and again measures the depth of the oil left in the tank after closing the valve leading into the company "line." From a record of the particular tank can be calculated the amount of oil delivered. Oil distributing companies and oil refineries store their crude oil and, often, refined products in tanks holding 50,000 to 100,000 barrels, or even more sometimes.

These are usually made of sheet steel riveted together (sometimes welded together) and are cylindrical in form with perpendicular walls. Wooden tanks are round but somewhat wider at the bottom than at the top, with upright staves held together by bands (occasionally rods) of steel. Vats sunk in the earth have been used at times, and large concrete reservoirs have also been tried, but generally there has been a great deal of loss through seepage. Some crude oils and many manufactured products are quite volatile and one of the problems on the industry is that of guarding against loss by evaporation, particularly in hot weather. Metal tanks are worse in this respect than those made of wood. The color of the paint on a tank has a great influence—the darker the color the greater the amount of heat absorbed from the sun's rays, the more the oil becomes heated and the greater the degree of evaporation. Aluminum paint is largely used nowadays for painting oil tanks and tank cars, because it has been found to reflect a larger proportion of the heat rays from the sun than any other substance cheap enough to be used in the quantities required. Incidentally, it makes them more "easy to look at" than they were when painted black, red, or some one or other of other colors. Another quite general practice is that of maintaining a sprinkler system on the top of the tank, and allowing the water to flow down on all sides of the top and down the sides of the tank—the evaporation of some of the water keeping the tank and its contents cool in the same way that a bottle of milk is kept cool by keeping a damp towel wrapped around it.

Oil storage tanks are frequent targets for so-called "bolts" of lightning, particularly in the summer time, and millions of barrels of oil have "gone up in smoke" during the past seventy years because of fires caused by lightning. Full tanks are less liable to burn than partly empty ones. In the latter case the space above the oil is often filled with a mixture of air and vaporized fractions of the oil comparable to the "mixture" you have in the cylinders of your "car" when it is functioning properly. The lightning explodes the mixture, blowing off the top of the tank, and the oil continues to burn so long as air can get to it to support its combustion. Formerly a "struck" tank was doomed to destruction with all of its contents except what could be pumped out from the bottom, or allowed to flow out from openings made near the bottom, sometimes by shooting a ball from a small cannon through the wall of the tank. Nowadays most large tanks are fitted with fire-extinguishing devices by which a foamy

mixture containing carbon dioxide gas can be flowed over the surface of the oil, thereby shutting off the supply of oxygen from the air and replacing it with the non-supporter of combustion, carbon dioxide. Steam is also frequently used. If the fire cannot be extinguished the oil will eventually get so hot that it will boil and the tank is then apt to "boil over" and the boiling, burning mass flowing over surrounding territory sets fire to other tanks and structures. For this reason large tanks are always surrounded by embankments to retain any oil that might boil over from the burning tank, and prevent the fire spreading to other tanks.

TRANSPORTATION The transportation of the oil to refineries and other markets has utilized many devices. At first it was filled into oaken barrels, bound with iron hoops, holding from forty to forty-four gallons each, and these were hauled by wagon (three to five barrels on a load according to the condition of the roads, which sometimes were hub deep with mud) to Oil City, where the barrels were loaded into barges and floated down the Allegheny River to Pittsburgh. Later some of the barges were loaded along the banks of Oil Creek and floated down this stream to the Allegheny River and thence to Pittsburgh. In times of low water, as in the summer, artificial floods known as "pond freshes" were created by releasing the water from dams farther upstream, the barge operators having been notified on what days such floods might be expected. Sometimes there were accidents and barges got jammed together, occasionally one breaking up and its oil floating down stream in the barrels or, when barrels were broken, as a film on the surface of the water.

The Atlantic and Great Western (now the Erie) Railroad was extended to the oil country in 1862, and the Allegheny Valley (now the Pennsylvania) Railroad was run from Pittsburgh to Oil City in 1866. Thereafter the oil barrels were hauled from the wells to convenient points along one or the other of these railroads and loaded onto cars, but the barrels were prone to spring leaks and there was much loss. About 1865 there were made special "oil cars" consisting of two fifty-barrel wooden tanks on a flat car, one over each truck. By about 1871 these were superseded by flat cars on each of which lay a cylinder made of boiler plate, the capacity being about eighty-five barrels. The same type of car has been in use ever since but the tanks now hold 200 to 250 barrels each. They are rarely used for transporting crude oils, however, but are much used for refined products—kerosene, gasoline, lubricants and fuel oils.

PIPE LINES

Somebody proposed the use of pipe lines as early as 1860 but the only kind of pipe available at the time was put together with slip joints, and there was much leakage. Screw-jointed pipe came into use about 1865, since which time crude oil has been largely transported through pipe lines, not only from the wells to the distributing stations and refineries, but also for hundreds of miles across the country, particularly from inland points to the seaboard, where are located some of the largest refineries in the country. It seems strange to speak of such a thing as friction when one is talking about oils, but there is friction between the oil flowing through a pipe and the walls of the pipe, and this makes it necessary in long-distance transportation to have "pump stations" located at intervals along the "line" to "boost" the flow. For the more viscous oils (so-called "heavy oils") the pipe lines are sometimes rifled like a gun barrel and are kept lubricated with a stream of water passing along with the oil. When pipe-line transportation was first started it met with considerable opposition on the part of the oil wagon drivers who had visions of losing their jobs, and some lines were torn up almost as soon as laid. The men soon found that their fears were unfounded. While they had fewer long hauls they had many more short hauls, and were not compelled to be away from their homes or boarding houses so much, and had more time for recreation at night. However, "hauling oil" gradually died out as a livelihood, and the men engaged in it found other means to make a living, often less conducive to loss of temper and the attendant flow of profanity. The condition of oil country roads during much of the year made "hauling oil" anything but an easy job. Possibly the strength of character developed in the pursuit of this work played an important part in the subsequent achievement of financial success in other phases of the "oil business" by a considerable number of men who "got their start" in this way. A man who had the stamina to work himself out of the difficulties that these drivers often found themselves in would be well fitted to fight his way to the front in almost any line of business.

MANY VARIETIES

Chemically speaking we cannot properly use the the word "petroleum" as applying to the oil obtained from the various oil fields and strata, but should use the plural form of the word ("petroleums"), because there are wide variations in the chemical composition of oils

from different localities, and, indeed, in oils obtained from different strata in the same well. In Pennsylvania in some localities oil has been obtained from as many as five strata, and there are decided differences in the properties of the oils obtained from these strata. "First sand oil," obtained from rather shallow depths, has a "heavy body," is free from "light oils" (readily volatile substances) and can be used, with little or no refining, for lubricating purposes; "second sand oil," obtained from a somewhat greater depth, has considerable "body," along with lighter fractions which have to be distilled off, the less volatile residue being suitable for lubricating purposes; "third sand oil" and "grey sand oil," obtained from still greater depths, are decidedly more limpid, contain large percentages of light fractions (hence are particularly suitable for the production of gasoline and kerosene), often contain considerable dissolved gas (are said to be "lively").

Generally speaking, all petroleums are complex mixtures of members of one or another of a number of series of hydrocarbons (the name given to compounds composed only of the elements hydrogen and carbon), sometimes containing small percentages of derivatives of some of these hydrocarbons. Pennsylvania, West Virginia and some Ohio petroleums are chiefly mixtures of hydrocarbons of the Marshgas Series (also called "paraffin series," "saturated series," and "methane series"), and are said to have a "paraffin base." Russian petroleums are mixtures of hydrocarbons of an entirely different group (the "naphthenes" or "polymethylenes"), while California petroleums are still different, and are said to have an "asphalt base." Certain Ohio and certain Texas petroleums contain small percentages of sulphur derivatives of certain hydrocarbons, are characterized by extremely disagreeable odors, and, on being burned, produce sulphur dioxide (the same gas that is formed when sulphur burns); and, of course, this oil must be specially treated to produce good kerosene and gasoline. Persons who have indulged in more than one "crude-oil shampoo" can now understand why one may seem so entirely different from another.

The differences in composition not only account for different degrees in fluidity and differences in odor, but also for differences in color. I show you one here from Clarion County, Pa., which is about a good straw color, here is one from Bradford County, Pa., and another from West Virginia which are dark green as you look at them and dark red as you look through them, here is one from

Texas which is a very dark brown, and another from California which is black. You will note that many have a greenish fluorescence as you look at them in certain ways (the oil man calls this fluorescence "bloom").

Petroleums are usually lighter than water and immiscible with it, but there are considerable differences in the specific gravities of the different varieties; and when we come to the different products of the refining of petroleums we find even wider differences often in the gravities. In this country the "gravity" of petroleums and their derivatives are generally determined by a special hydrometer for liquids lighter than water, an instrument which floats on the liquid under examination, with part of it submerged. The lighter the liquid the greater the portion submerged, hence, the greater the figure representing the gravity of a light liquid the lighter the liquid. For example, "seventy-five degree" gasoline is lighter (and, incidentally, more active and dangerous) than "sixty-eight degree" gasoline. Because it contains a larger proportion of the more volatile hydrocarbons, one can start a "cold" engine more quickly with it than with the "sixty-eight degree" gasoline. Low gravity gasolines give little or no trouble in warm weather, but sometimes do give considerable trouble in the winter.

PRICES

The market prices of crude petroleums, like the prices on other commodities, are dependent upon many factors, among which may be mentioned:

a. Distance from market and relative cost of transportation.

b. Supply and demand. The opening of a prolific new field generally depresses the price, while an increased market for gasoline, as in summer time, stiffens the price.

c. Manipulation of prices. At one time there were a number of "oil exchanges" in the country, and prices sometimes fluctuated very much from day to day. These "exchanges" went out of existence years ago, and prices fluctuate very little now.

d. Grade of oil. In this country "Pennsylvania grade" usually commands the highest price, as it refines easily and produces a larger percentage of the products in demand—gasoline, kerosene and lubricants. This grade brings from 80 to 200 per cent. higher prices than other oils. In California the price is dependent upon "gravity" more, perhaps, than in any other state, the higher the figure expressing the

gravity the greater the price offered. The influence of the motor car is plainly seen here, for the greater the figure expressing the gravity the greater the possible yield of gasoline. We have stated elsewhere that the production of the Drake well sold for around $20 a barrel (about sixty cents a gallon). This was in 1859, and as late as January, 1860. By December, 1860, the price was down to $2; by December, 1861, it was down to ten cents; by December, 1864, it was as high as $11.50; in December, 1873, it was as low as eighty-two cents; between 1878 and 1898 the price rarely got above $1, and since 1898 it has rarely gotten below $1, and about the year 1917 it was as high as $6. In recent years the price has held fairly closely between $3 and $4. The prices here quoted were for "Pennsylvania grade."

REFINING

There has been some use of crude oils from certain districts, notably a small one near Franklin, Pa., direct for certain types of lubrication; and there are some that are fit for little else than fuel, hence used direct for that purpose; but most petroleum products represent just portions ("fractions") of some grade of crude oil. The main feature of "oil refining," so called, at first was a form of fractional distillation, and even today it is an important feature. In 1860 there were in this country fifty-three "refineries" devoted to the manufacture of a "coal oil" from soft coal by distillation. In 1858 the operators of one of them tried the refining of Tarentum crude oil from salt wells, and proved that a better product than "coal oil" for illuminating purposes could be made from petroleum. With the increased production of petroleum inaugurated with the sinking of the Drake well the "coal oil" refineries turned to refining petroleum, or in some instances went out of business. For quite a number of years the "stills" used were rather simple affairs and the condensation of the distillates equally simple. The stills were made of boiler plate, were cylindrical in shape, were enclosed in masonry, and were heated by direct firing—building the fire underneath the still. In one type the stills were short squatty cylinders sitting on end, and were called "cheesebox stills," resembling an old-fashioned wooden cheese container. The other type showed long cylinders lying on the side, and called "wagon-body stills." To the upper part of stills of either type there was fitted a sort of dome from which a pipe or pipes led to a condenser. In the manufacture of some products live steam was introduced into the contents of the

still at certain stages of the operation, the steam carrying over into the condenser some fractions that could not be easily distilled direct. The distillate flowed from the end of the condenser coil into a "catch box" in the "tail house" (now more politely called the "receiving house"), and thence into one or another of a series of receiving tanks, the direction of flow being determined by the opening of a valve on a line leading to one of the tanks, and the closing of valves in lines leading to the others. The distillate suitable for gasoline or benzine went into one tank, the kerosene fraction into another, and so on. The "cuts" (changes of receiver) were made "on gravity." From time to time the "stillman" collected some of the distillate at the "catch box" and tested it with the hydrometer, and made his "cuts" when the gravity of the distillate was that desired in the particular product.

CRACKING

There are refinements of operation but in many particulars the processes today are not very different from what they were nearly seventy years ago. For many years the most valuable product of petroleum refining was kerosene (known to many only as "lamp oil"), and efforts were constantly being made to find methods for increasing the yield, the kerosene fraction in some oils being very small, and in none very large. It was found that by modifying the stills somewhat, and modifying the firing practice, it was possible to break down ("crack") some of the higher hydrocarbons left in the still after the benzine and kerosene fractions had been distilled off, the products of the "cracking" process being essentially the same as the kerosene fraction, and thus each barrel of crude oil was made to yield more kerosene than it naturally contained. Another practice was to leave as much of the benzine fraction in the kerosene as the operator could "get away with"—a reprehensible practice, as it made the product more subject to explosion when used in lamps, particularly when the bowl of the lamp was nearly empty (in which case the bowl of the lamp would often become hot, thus vaporizing some of the benzine fraction, and the mixture of benzine vapor and air in the upper part of the bowl becoming an explosive mixture that could be easily ignited by the flame of the lamp through the small air vent alongside of the wick). This practice brought about the speedy enactment of legislation requiring all kerosene sold to come up to a certain "fire test." There is no need for such legislation today, for the temptation

today is to leave as much kerosene in the gasoline as the operator can "get away with." "Cracking," by means of specially devised apparatus to bring about the decomposition of complex hydrocarbons into simpler ones under the influence of high temperatures and great pressures, is responsible for the large percentage of gasoline that is being made from every barrel of crude oil, very much larger than could be obtained by the older processes. Certain groups of substances found sometimes in crude oils, but more often formed in the distillation process, were early found to be removable by the use of concentrated sulphuric acid, hence "treating" of petroleum distillates is an old practice. The usual procedure is to flow the distillate into a tall lead-lined cylindrical vessel, add a few per cent. of the acid, and mix the two thoroughly by blowing air through it, allow the "sludge acid" to settle out, draw it off from beneath the oil, and thoroughly wash the oil with water containing some sodium hydroxide, then with water. Colors in oils are sometimes removed by sun bleaching, sometimes by use of chemicals, but most generally by filtration through large quantities of some color-absorbing granular powder. Bone black was at one time largely used, but it has been largely supplanted by fuller's earth. It may interest some of you to know that there are over 400 refineries in this country today, handling several million barrels of crude oil daily.

The seventy years that have elapsed since the drilling of the Drake well have witnessed the development of a tremendous industry the ramifications of which have spread into all parts of the world and have affected directly or indirectly almost every other line of human endeavor. One needs only to consider the use of kerosene for illumination, gasoline for motor fuel, and the heavier bodied products as lubricants, to realize the truth of this. It is impossible to estimate the stimulus given to night work and study by the kerosene lamp, the impetus given to transportation on land, on water and through the air by the gasoline motor, and the speeding up given to all classes of machinery by the petroleum lubricants. Whereas in Drake's day petroleum was being thought of only as a medicinal agent, as a possible illuminant, and some parts of it as a grease remover for wool, today there are hundreds of uses for its products, and one could hardly conceive of a greater calamity that could happen to the human race than that of being suddenly deprived of them.

NO MORE PAIN

By E. Fullerton Cook, Ph. M.

A PATIENT today stands before a fluoroscope, the doctor turns on that mystery ray, commonly known as x-ray, and can actually see the beating heart, the structure of the lungs and the manner of their functioning or perhaps the working of the entire alimentary system. Yesterday this would have been impossible and unbelievable, perhaps tomorrow we may turn on a y or a z ray, and with clear vision, trace the intricate form and workings of the marvelous network of communication and power, the nervous system which reaches into every corner of the human body. Some day we may have this opportunity to study the mechanism of human power.

E. Fullerton Cook, Ph. M.

Fortunately the picture has been painted in great perfection by those anatomists who have painstakingly traced the sources of impulse, the lines of communication and the responsive cells that leap to obey a command of the will or gather facts for the intellect to analyze and use. Perhaps in life the picture might reveal some detail not now known, or a delicate instrument might register the electric impulses carrying a message from brain to eye, but the picture now is well known and graphically illustrated in the outline before us.

THE CENTRAL STATION OF REASON

The spinal cord, the medulla oblongata, the cerebrum or brain and the cerebellum, housed in their closely fitting bony shells, constitute the central nervous system and the intellectual center of life. From this central station and to this seat of reason and knowledge pass the sensations or impulses which express the will and power of man. Literally millions of tiny fibres transmit the messages back and forth, serving of themselves only as the means of communication. Each fibre is made up of a central core technically known as an "axis cylinder," which transmits the impulses. This is surrounded by a sheath of

fatty matter known as *myelin,* and the whole protected by a membraneous sheath known as the neurilemma. A nerve is made up of several thousand such fibres, each capable of acting as an independent path of transmission.

If an outgoing nerve be traced it will usually be found to terminate among the epithelial cells of the skin or mucous membrane, ending in something like a capsule or bulb wherein lies the sensory ending. The other terminal of this type of nerve is found in some section of this central system in the form of a nerve cell. These cells are sometimes irregular, somewhat star-like in shape, or again globular, the mass of cells constituting the structure of these vital organs. From the brain or cerebrum which makes up the larger mass of "gray matter" within the cranium, originate and are received those impulses which give expression to intelligence. Here are centered the controls responsible for the sense of smell, for sight, for all voluntary movements, for sensitiveness in face and teeth and other parts of the body, for the appreciation of sound waves, and for the sense of taste.

The spinal cord, at the opposite end of the central nervous system, performs a different function from the brain in that it receives no sensations nor does it direct voluntary movement. It does, however, originate reflex actions, stimulated by impressions made upon it by certain impulses such as heat.

Such phenomena as intestinal peristalsis, the contraction and dilation of the pupil, the reflex action which closes the glottis and the muscular action involved in coughing due to the presence of a foreign body, are illustrations of the action due, at least in part, to impulses originating in the cord. The muscular movements of digestion, of respiration and of walking are also partly related to stimuli originating here, but so interrelated are nerves between the brain and cord that often the former may exercise its superior authority and control what normally functions under the cord.

The medulla oblongata serves as a means of communication between the brain and cord but possesses other important functions. Here especially are centered the controls of respiration and it has been called the "vital spot" for its serious injury results in almost instantaneous death. It also stimulates reflex action related to the secretion of saliva, vomiting, sneezing, secretion of sweat, the inhibition and acceleration of the heart and other less important functions.

The cerebellum serves primarily in the coordination of voluntary muscular movements. For instance, with this removed, an animal may still raise the foot with normal vigor but will not know where to put it down.

But to complete this picture there must be seen a second system of nerves, known as the "sympathetic." This consists of an aggregation of nerve cells in modular enlargement, usually called "ganglia," mostly ranged on either side of the spinal column. These are closely associated with the nerves of the central system and function in coordination with them but have definite relation to the action of non-striped muscles controlling the circulatory system and secretion glands. Its only direct connection to striated muscle is to the heart. The sympathetic nerves definitely effect secretions, digestion, nutrition and heat production.

In the quest for the magic power of a pain destroyer, it is this delicate system of communication which is involved, for it is seen that the nervous system is the center of all sensation, therefore the seat of pain and one of the keys to its elimination. For immediate relief, a temporary numbing must be produced. If the effect is to be local, only the group of associated terminal nerve endings need be reached, but if general and complete anesthesia is wanted, the very centers of sensibilities must be affected and for the time rendered inoperative. But it must not be forgotten that a prompt return to consciousness and the absence of any injury to the patient are equally essential qualities for such an agent to possess.

There are occasions in every life when pain is experienced; in youth functional disturbances may come from the eating of green apples or contact with a parental strap, or later it may be from the pangs of maternity or a broken leg or one of a thousand possible causes. But pain has always been considered the opposite of pleasure and we ask for quick relief.

Is it any wonder that from the dawn of civilization efforts have been made to overcome this curse?

EARLY BATTLES AGAINST PAIN

Mankind must have always possessed the trait of curiosity, at least it is still a dominant quality influencing the actions of our traditional progenitors and leads many a monkey into trouble. But slow and painful has been the accumulation of knowledge and especially judgments based upon facts.

Primitive men and women must have gone about tasting leaves and roots, seeds and flowers, and then observing the effects. In a higher civilization, the more potent drugs were tested on prisoners or slaves, but it is certain that our knowledge of drug action has come only through the tragic loss of many lives. Among the earliest records of a specific drug capable of relieving pain is one from the writings of the Greek historian, Herodotus, about 500 B. C., who reported that the tribes along the Danube and south to India used a variety of hemp, the fumes from which produced high mental exaltation, followed by sleep. This suggests the narcotic, Cannabis, still in use by the natives of that territory, under the name Hashish and recognized as a narcotic drug today by most pharmacopœias of the world.

In the great ancient civilizations, including Egypt, Assyria and Babylonia, there are evidences that vegetable substances were known and used to produce sedative or anodyne effects. Homer in the Odyssey described the use by Helen of a drug which "she cast into the wine and those who drank forgot all sorrow and experienced the lulling of pain and anger." "Mandragora," supposed to have been a solanaceous drug similar to belladonna, was chief among these ancient herbs employed to ease man's sufferings.

MANDRAGORA

One of the tales of antiquity which illustrates the reputation acquired by the mysterious drug mandragora is associated with the campaigns of Hannibal in Africa, about 200 B. C. Being attacked by a large army of savages, he retreated but left on the field a large number of vases containing wine steeped in mandragora. These were captured by the natives who drank freely of their contents and were soon reduced to a condition of stupor. The strategist anticipated this and returning to the field with his army, quickly destroyed the helpless enemy.

In the writings of Dioscorides and Pliny, who lived in the first century, specific reference is made to the steeping of mandragora root in wine and the administration of this decoction to the patient about to the operated upon, "to render the cutting painless." In the second century, Galen again referred to the "power of mandragora to paralyze sensation and motion."

With so remarkable a reputation, it is strange that so little is known today of mandragora. The only explanation would seem to be that its powers were greatly exaggerated for it is not likely that

a drug actually having the potency attributed to mandragora would have been lost. Certain it is that the *Atropa Mandragora* of today fails to measure up to the reputation established by its famous ancestor.

It is true that atropine, a powerful alkaloid from the related plant belladonna, is now largely employed as a treatment preliminary to ether anesthesia, but this drug is used today not for the purpose of relieving pain but only to lessen the mucous and salivary secretions during the operation.

THE SLEEP-PRODUCING SPONGE

In the third century there are records of the Chinese surgeon, Hoa-tho, using a preparation of hemp to render his patients unconscious during an operation, and for centuries another form of pain reliever was in use known as "Spongia somnifera" or "Soporific Sponge." Theodoric, about the tenth century, described the making of this, calling it a "flavor" from opium, mulberry, hyoscyamus, hemlock, mandragora, and other plants. This liquid was applied on a sponge to the nostrils of the patient to produce insensibility to pain and one may well believe that this combination, not by inhalation but by absorption through the mucous membrane of the nose, could induce effective narcosis. It is even thought that perhaps the sponge, dipped into "vinegar" and offered Christ on the cross, may have been of the nature of the "soporific sponge" and intended to produce a stupor and insensibility to pain.

Hugo recommended the local application of compounds of antimony, mercury, lime and arsenic to an operation site to produce analgesia, but the efficacy of this is doubted although it might have made an effective caustic.

That the physician kept before himself and his patients the ideals of anesthesia is evidenced by many facts, witness a verse by Du Bartas of the middle ages who wrote:

> "Even as a surgeon——
> Bringeth his patient in a senseless slumber,
> And griefless then, guided by use and art,
> To save the whole, cuts off the infected part."

Two other drugs, opium and alcohol, have the power to allay pain and lessen susceptibility to suffering and the time of their first use is unknown. The knowledge of the action of opium was not

universal for many centuries, in fact its use was limited to certain portions of the Near East until the Arabian school of medicine under Rhazes and Avicenna carried it in the tenth century into Western Europe.

Hippocrates, who was born 460 B. C. and is known as the "Father of Medicine," used the term "opium" for a plant juice having sedative action, although it is not certain that he referred to opium.

Heraclides, who followed Hippocrates, was the founder of the "School of Empirics," and he is credited with being the first recorded user of opium as an anodyne in painful diseases.

THE PRAISEWORTHY LAUDANUM

The history and uses of opium cannot be entered into here but after its introduction into Europe it played an important part in medicine. Dr. Sydenham, a famous English physician of the seventeenth century, credited with introducing the liquid preparation known as "Laudanum," wrote: "Of all remedies which a kind Providence has bestowed upon mankind for the purpose of lightening its miseries, there is not one which equals opium in its power to moderate the violence of so many maladies, and even to cure some of them. Medicine would be a one-armed man if it did not possess this remedy."

Opium, or its alkaloids morphine and codeine, are still among the most important drugs in use today. It is true they must be employed with caution and under rigid control to prevent their misuse, but as a preliminary to ether anesthesia, to quiet the patient and lessen post-operative suffering, the use of morphine is almost routine, while codeine has its own place as a sedative in many conditions of irritation or unrest, and that without the dangers usually associated with opium.

The other narcotic, alcohol, older than history, has doubtless been utilized through the ages to render a sufferer less sensible to pain although today it is rarely administered specifically for that purpose. However, in the days before modern anesthesia, alcoholic drinks were used to produce narcosis before painful operations and to relieve other painful conditions although it was only partially effective.

It may be remembered that in Cymbeline, Shakespeare makes Cornelius, a court physician of the seventh century, prescribe a drug

which "will stupify and dull the sense awhile . . . but there is no danger in that show of death it makes" and although the drug referred to is but speculative it again indicates the effort of the medieval physician to foster the current belief that such a drug existed.

About the same period Valverdi and other Italian physicians attempted to produce unconsciousness by compressing certain areas in the neck, a process said to have been practiced by the ancient Assyrians for child circumcision.

HYPNOTIC ANALGESIA

Another forward step was taken in the seventeenth century (1661) when Greatrakes produced "magnetic sleep" by making passes over the body and in 1766 when Mesmer evolved his theory of "animal magnetism" which, a century later, evolved into the modern practice of hypnotism. Many

1—The Horror of Amputation Before Anesthesia.

cases were reported in which painless surgical operations were performed in India by Esdaile under hypnotic anesthesia. Unfortunately hypnotism as an anesthetic is limited to those patients who are subject to hypnotic suggestion.

ANESTHESIA BY BONDAGE

But all of these earlier attempts were limited in use and effectiveness and old illustrations and records evidence the usual need, in serious operations, of strapping or holding the patient on the operating table with the consequent horror of frightful suffering. In fact during the century preceding the discovery of anesthesia, it was quite beneath the

dignity of most medical men to do surgical work. What was attempted was of the most primitive character, chiefly amputation of fingers, toes, or perhaps the forearm or the leg below the knee, and these were not only painful but dangerous. The introduction of the tourniquet by Petif in 1718 was a marked advance in technique as it largely eliminated the danger of hemorrhage and made possible more time for the operation and the abandonment of cauterizers. It was not until 1745 that the association of barbers and surgeons was abolished in England, by an Act of Parliament, and from that time surgery became more honored as a branch of the medical sciences.

2—An Operation Before the Introduction of Ether.

The advance in the knowledge of anatomy of this period was another reason for more success in surgery and in fact, the origin of several important operative methods of today date back to this period. However, without a knowledge of bacteria, conditions were often deplorable and it is no wonder that both the patient and the surgeon dreaded the ordeal. Dr. J. Collins Warren, in an address delivered before the American Surgical Association in 1897, said, "The horrors of surgery without anesthetics caused even surgeons to look upon operative surgery as the lowest, poorest side of their profession. An operation was attended with almost the formality of an execution. The hardiest of doctors are described as steeling themselves to the duty of operating. John Hunter, one of the best known surgeons of this time, says 'no surgeon should approach the victim of his operation without a secret dread and reluctance.' Aber-

nethy felt the strain of operating keenly and is reported to have felt such repulsion to operations that he regarded them as having no place in surgery as a science."

"LAUDABLE PUS"

Not only was the operation painful but the treatment during healing was torture, for no wounds were healed by "first intention" and dressings were forced even between ends of broken bones and into wounds to prevent them from healing on the surface.

Dr. John C. Warren, who performed the first public operation with ether, a year later wrote, "In order to form a proper estimate of the value of the new practice, we should endeavor to realize the mental condition which formerly preceded a surgical operation. As soon as a patient is condemned to the knife what terrors does his imagination inflict? How many sleepless nights and horrible dreams and sinking of the heart does he experience! What apprehension of dangerous bleedings of wounds of vital parts and even sudden death does he paint to himself? And when to these is added the dread of insupportable pain, what a frightful picture presents itself to his mind. No wonder many persons are unable to bring themselves to submit. No wonder that some, worn out to desperation, are led to anticipate their sufferings by a voluntary death."

"A SPEEDY BLADE SPARES MANY AN ACHE"

Robert Liston in teaching his surgical students two years before the introduction of ether said, "The divisions of the skin must inflict pain but there is a way to render it less severe. The mode of cutting must be acquired to attain this desired end. In the first place, you must not divide the skin by scratches. You must carry the knife completely through the tissues at once, and doing it with rapidity you will save the patient a great deal of pain." Also at this time, many surgeons abandoned the use of the knife and employed only caustics in treating tumors.

THE DAWN OF A NEW DAY IN SURGERY

Near the close of the eighteenth century, however, with new light in the chemical sciences, there came the hope and promise of a complete anesthesia or unconsciousness. Cavendish in 1766 discovered hydrogen, Rutherford (1772) discovered nitrogen and Priestley (1774) discovered

oxygen and nitrous oxide. But for many years little progress was made in the utilization of these or other products as anesthetics. It is recorded, however, that in 1795 Dr. Pearson of Birmingham, England, employed ether, which had been known since 1540, for the relief of asthma and that Sir Humphrey Davy, who, when only twenty years of age, was employed by Dr. Bedoes of Bristol to study the medical effects of various gases and who, after two years of work, wrote an essay in 1799 on "The action of nitrous oxide when inhaled," in which he wrote: "As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place."

Also Faraday, in 1818, wrote: "When the vapor of ether, mixed with common air, is inhaled, it produces effects similar to those occasioned by nitrous oxide." He even called attention to the necessity of using caution in experiments of this kind as "a gentleman was thrown into a state of prolonged insensibility by its use in this way."

ETHER FROLICS

It was also quite popular at this time for lecturers to demonstrate for entertainment certain recently discovered chemical and physical phenomena including the intoxicating character of ether and also for groups of young people to engage in what at that time were known as "ether frolics," when all would inhale the vapor and exhibit the characteristic stimulation, followed by unconsciousness, if carried that far.

Nitrous oxide was similarly used and the *Philadelphia Gazette* of 1820 carried advertisements offering it for sale for that purpose. In fact it was ultimately the effects of these demonstrations and experiences which forced the recognition of these substances as true anesthetics, and strangely enough almost simultaneously in distant parts of the country.

It is recorded that at an entertainment in Athens, Georgia, in 1840, when the effects of ether were being demonstrated, a young man named Wilhite compelled a negro boy to inhale ether. The boy resisted but it was forced upon him and he became completely insensible. From that time it became a common practice in that dis-

trict for young people at social gatherings to inhale ether for its effects and the resulting fun.

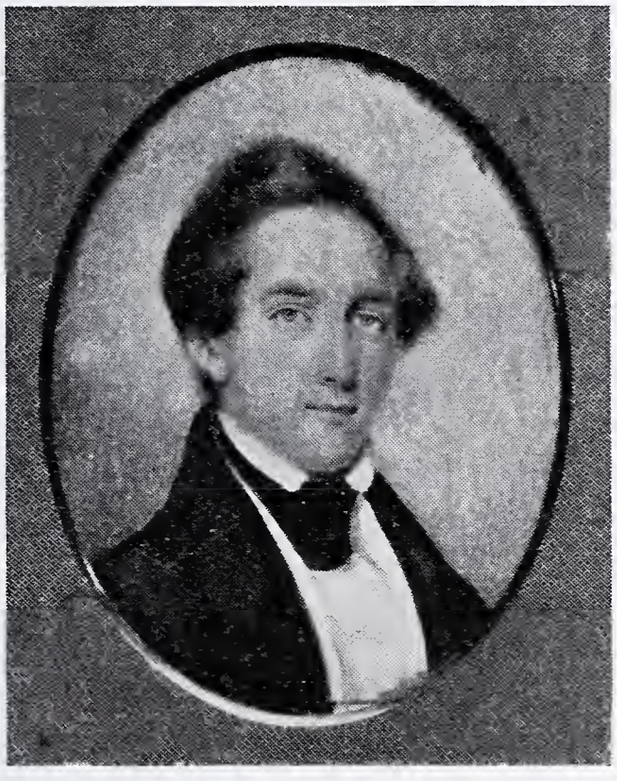
Dr. Crawford W. Long, who had graduated from the Medical Department of the University of Pennsylvania a few years before, having participated in such parties, noticed that injuries or bruises were sometimes sustained while unconscious, and that these at the time caused no pain. This suggested its use in operations and in 1842 he and his assistants used it with complete success while performing a minor operation, the patient feeling no pain. He continued its use in other cases but at the time made no attempt to announce his discovery.

3—Dr. C. W. Long, Who First Used Ether to Render Operations Painless (1842). A Crayon Portrait by His Daughter in 1842.
(Courtesy of the U. S. National Museum.)

In 1844, Dr. Horace Wells, a dentist of Hartford, Conn., also happened to see a platform demonstration of the temporary insensibility produced by the inhalation of nitrous oxide and also observed that the subject received injuries while unconscious but apparently without pain. Wells determined to try it upon himself and persuaded

Colton, who had given the demonstration, to come to his dental office, and administer the gas while his friend Riggs extracted a diseased tooth.

The complete absence of pain was so convincing that Wells interested a Boston dentist, formerly his pupil, named William T. G. Morton, and they arranged a public demonstration at the Harvard Medical School but only with partial success as apparently not enough gas was used. Wells was hissed from the room by the students and denounced as an impostor and, to quote one of his defenders of later years, the trembling adventurer left the hall, went back to his home heartbroken, friendless, but not despairing.



4—Dr. William T. G. Morton, Who First Publicly Demonstrated the Use of Ether as an Anesthetic (1846).
(Courtesy of the U. S. National Museum.)

ETHER "ARRIVES"

Morton, however, continued his experiments and also tried ether at the suggestion of a friend, Prof. Charles T. Jackson, who as a chemist was doubtless familiar with the suggestion of Davy and Faraday. Convinced of its efficacy by experimenting on animals, at last Morton inhaled it himself and on returning to consciousness was convinced of the value of his discovery. Later he used it on a dental patient, Eben Frost, from whom he extracted a tooth and now, with confidence, he gives

a public demonstration at the Massachusetts General Hospital on October 17, 1846, with Dr. John C. Warren operating. All were instantly convinced of the importance of the discovery and anounced it to the world but Morton and Jackson try to patent it, under the name "Letheon" and while this was not allowed, it cast temporary discredit upon their part in the discovery.

It is of interest to note that Dr. Warren who performed this first public operation with ether anesthesia was at that time the leading surgeon in New England if not in this country but was well advanced in years. It is the more to his credit that he was willing to become a pioneer in this field and then most energetically to develop and promote its uses in surgery. Dr. Oliver Wendell Holmes, a contemporary, said of him, "We confess it to have been a noble sight when an old man was found among the foremost to proclaim the great fact—strangly unwelcomed as well as improbable to some who should have been foremost to accept it—that pain was no longer the master but the servant of the body."

THE STUBBORNNESS OF THE HUMAN MIND

Looking back upon this period it seems impossible that, with the need so pressing, the world should have had within their grasp the blessings of painless surgery for almost a half century before a few brave men had the vision and the courage to try it. The pointed suggestions from Davy and Farraday and the actual demonstrations repeatedly made upon the entertainment stage should have persuaded someone, years before, to put it to trial.

As Ashurst says, "Surgeons went on in every country cutting and burning, and patients went on writhing and screaming until October 16, 1846, when surgical anesthesia became the priceless heritage of the civilized world.

Dr. Holmes, while speaking to Harvard medical students in 1847, about this discovery, said: "In this very hour while I am speaking how many human creatures are cheated of pangs which seemed inevitable as the common doom of mortality and lulled by the strange magic of the enchanted goblet, held for a moment to their lips, into a repose which has something of ecstacy in its dreamy slumbers. The knife is searching for disease, but the fierce extremity of suffering has been steeped in the waters of forgetfulness, and the deepest furrow in the knotted brow of agony has been smoothed forever."

HAIL THE FIRST ANESTHETISTS!

With Wells, Morton and Jackson, all claiming credit for the great discovery and Long then bringing evidence of his own priority as a user of ether for anesthesia, it is not surprising that for years there existed a bitter controversy over who should be awarded the honor of first discovering a general anesthetic. Congress was importuned to award Morton $100,000 in recognition of his service to humanity. Groups of eminent physicians, medical societies, editors and congressmen took part in the discussion, and several congressional investigations were conducted. No official decision was finally rendered and ultimately the three contenders, Wells, Morton and Jackson all died tragic deaths in disappointment and poverty, and while Long never asked for any reward he did ask for official recognition of his claim and this today seems to be generally accepted.

To indicate the heated character of this controversy the following quotation from a Virginia editor who has espoused the cause of Wells is copied: "Defrauded of his honor, betrayed by his friends, deserted by good fortune, his body shattered by the constant use of all sorts of excitants, still experimenting on himself, his mind ill-regulated, impulsive, tortured by the cruel fate which seemed to await him—twas more than he could bear. Mankind looked eagerly here and there for their benefactor and found him at last in a suicide's grave."

HAIL THE FIRST ANESTHETIZED

While it required courage and faith for Morton and Dr. Warren to undertake the first public operation under ether, we should not forget the name of Gilbert Abbott, the patient who voluntarily braved the unknown and accepted a death-like experience and with no positive assurance of an awakening.

Dr. William H. Keen, in an address before the Massachusetts General Hospital on "Ether Day," sixty-nine years after the first operation under ether said, "I have often called the attention of my classes to a patient lying limp and apparently almost lifeless on the operating table. Lift the arm and it falls as though it were that of a corpse, touch the sensitive eye and the lids do not move, cut the tender skin and it elicits no response. Will he ever wake up? May not the flickering flame of life gradually fade away forever? Have

I not unwittingly killed this man? Such must have been the insistent questions in the mind of those intrepid adventurers on that first momentous occasion. How eagerly they must have watched the first faint evidence of returning consciousness! Had that young man died then and there for how many years would the blessings of anesthesia been withholden from the human race?"

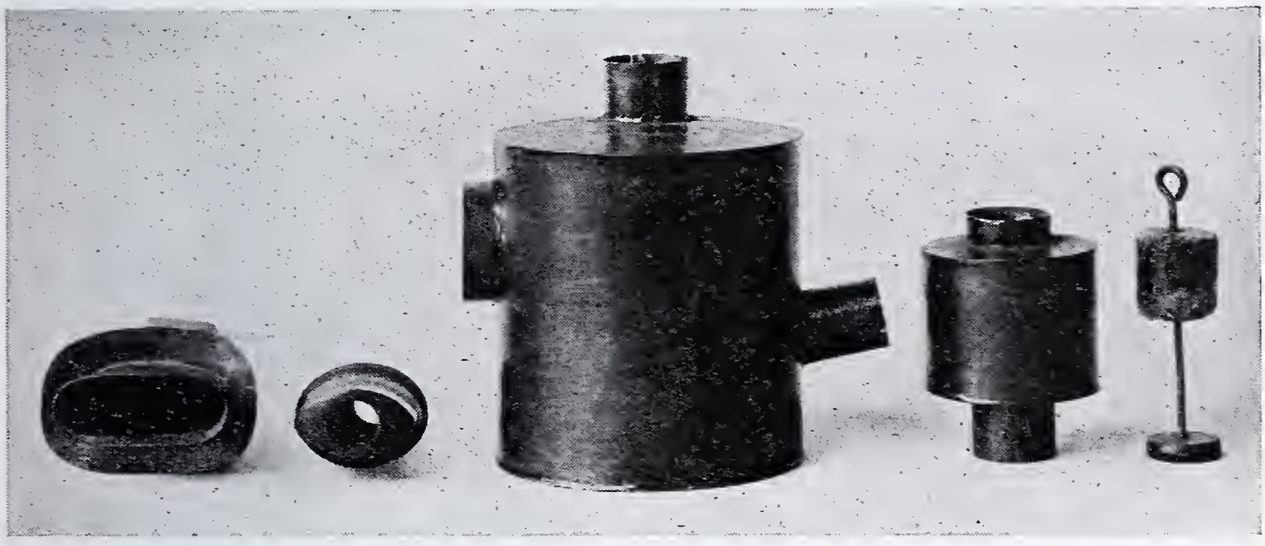
5—Ether Inhaler Patented by Morton and Gould, November 13, 1847.
(Courtesy of the U. S. National Museum.)

It is of passing interest to know that the term "anesthesia," classically written "anæsthesia," was suggested at the time of its discovery by Dr. Oliver Wendell Holmes and received instantaneous and universal recognition.

GENERAL ANESTHESIA BY INHALATION

The epoch-making discoverey that nitrous oxide and also ether, when administered by inhallation, produced complete insensibility to pain, was revolutionary and far-reaching in results. Modern surgery was half born at the moment of this discovery, and needed but the work of Pasteur and Lister a few years later to rise full grown in the midst of a needy world.

The discovery of the use of ether quickly spread to Great Britain and the first operation there with ether was in December of 1846 at the University College Hospital at Edinburgh by Dr. Liston. Dr. James Young Simpson, a noted English gynecologist of the period, tried it the next month in midwifery cases, with marked



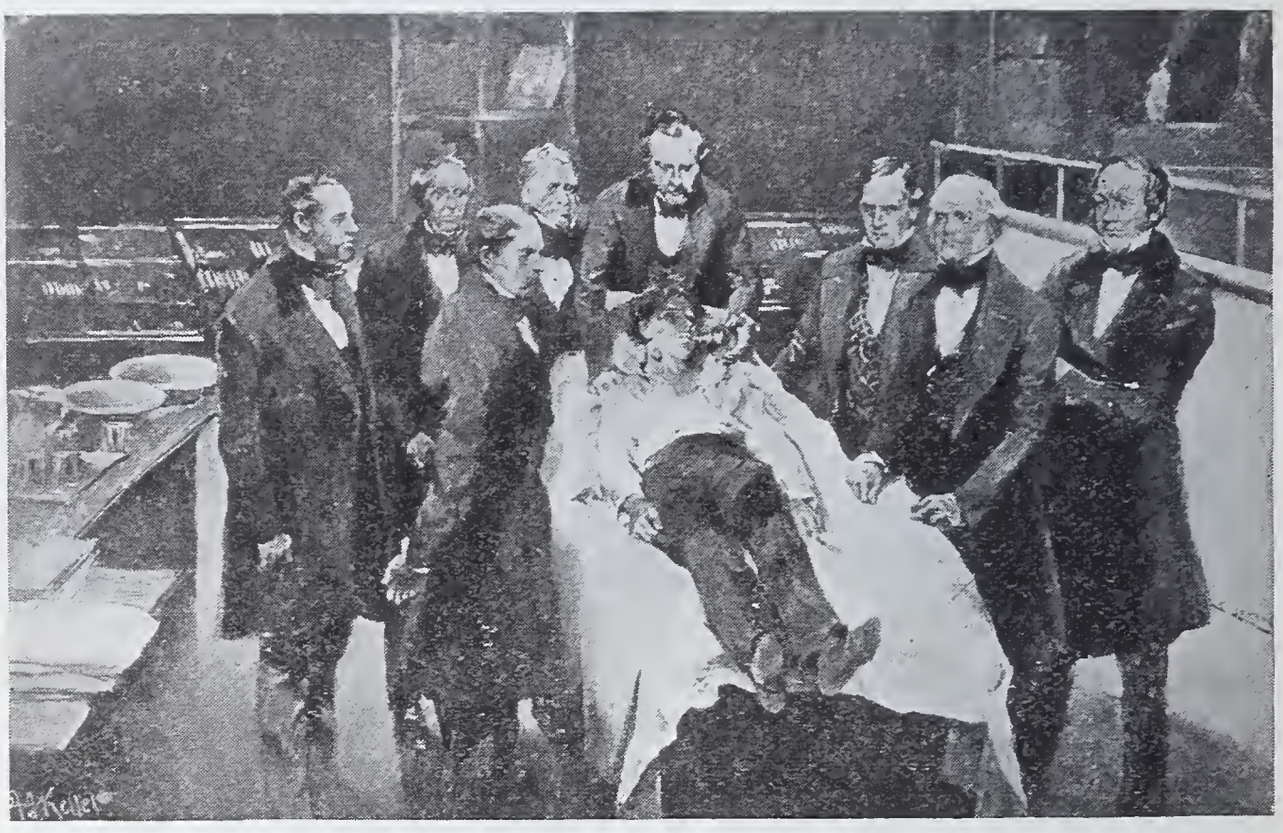
6—One of the First Ether Inhalers, Said to Be Identical With the One Used for the First Public Anesthesia in 1844.
(Courtesy of the U. S. National Museum.)

success. A Scotch pharmacist, named David Waldie from Liverpool, who had been doing some experimental work with the recently discovered chloric ether, now known as choloform, met Simpson in Edinburgh and suggested the use of this substance instead of ether. He promised to send some of it on his return to Liverpool for Simpson to try, but a fire in his laboratory prevented him from doing so immediately. Simpson's interest being aroused, he secured some of the substance from elsewhere but finding it so heavy doubted its value. However, on November 4, 1847, he and two assistants, Duncan and Keith, determined to try it personally and inhaling some of it from a tumbler all were rendered unconscious. Simpson was the first to recover and found the others on the floor still unconscious although all quickly recovered. A few evenings later they induced

a niece to try it, which experiment was also a success with the result that Simpson began to use chloroform extensively in his practice and his influence rapidly caused it to gain greater popularity in Europe than did ether.

This may have been heightened by a most unfortunate happening in Berlin where the first use of ether caused the death of the patient and thus greatly retarded its general introduction, abroad, in place of chloroform.

Chloroform chemically is "Trichlormethane" having the formula $CHCl_3$. This substance had been discovered by Dr. Samuel



7—Painting Illustrating the First Public Operation Under Ether at the Massachusetts General Hospital in 1846.
(Courtesy of the U. S. National Museum.)

Guthrie of Jewelville, N. Y., as resulting from the action of chlorinated lime on alcohol. He announced it in May of 1831 and later in the same year Soubeiran of France and Liebig of Germany announced similar products. In March of 1847 Floureus, a French chemist reported to the Academy of Science in Paris that he had produced anesthetic affects on animals by the use of chloroform but it is not likely that Simpson knew of this paper.

The first belief that chloroform had pronounced advantages over ether for general anesthesia because of its more prompt action, its

smaller dose and less objectionable odor, was soon offset by the discovery that death more often occurred during its administration than when ether was employed. The first action of ether is that of a stimulant and under its effects the force of heart action is increased while chloroform is a powerful sedative and depressant, acting directly upon the heart and this difference in physiologic action explains the great danger from the use of chloroform.

Having already discussed the structure of the nervous system, it will be realized that any substance which paralyzes the entire system will cause instant death. However, if the agent of anesthesia

8—Modern Ether Anesthesia, Painless and Aseptic.

is selective and at first only renders inoperative the sensory nerves and is held at that point, leaving those nerves still functioning which control the heart and respiration and the other involuntary forces, then life will not be endangered. This is why the anesthetist, the one who administers the anesthetic, performs a part equally or even more important than the surgeon, for those who administer the anesthetic

literally holds the spark of life in their hands. That is why the pulse and the breathing and the reflexes are so closely watched throughout anesthesia.

Keep in mind the importance of the anesthetist in every operation; not only is life itself in his hands but the method of administration is often responsible for the absence from or equally the suffering attending post-operative complications involving bronchial or pulmonary inflammation. Only an experienced and specially trained operator should be permitted to administer the anesthetic.

At first ether and chloroform alone were available for general anesthesia, nitrous oxide being employed primarily for dental operations, mainly the extracting of teeth, when only a momentary insensibility was required. But the scientist is ever striving for improvements so that a number of other substances have been tried including the so-called "A. C. E. mixture" (alcohol 1, chloroform 2, ether 3 parts), which has little use today. The most important of the new anesthetics for inhalation is Ethylene, a gas which seems to be meeting with general favor notwithstanding its great inflammability and the necessity for extreme caution during its use. Ethyl chloride and acetylene are aso used to some extent for general anesthesia.

Another modification of the older methods is the return to nitrous oxide for the initial stages of anesthesia, its effects and adminstration being less difficult for the patient than straight ether. When a state of complete unconsciousness is secured, the anesthesia may be maintained by the introduction of the particular anesthetic preferred.

The technique of administration has been studied intensively for years and conditions and preferences will govern the selection of the method to be followed.

ANESTHESIA BY RECTUM

This method is applicable only in special cases such as in the use of the bronchoscope when ordinary methods would not be applicable.

Usually the patient is anesthetized by one of the usual methods and the anesthesia only maintained by the injection of an ether mixture into the rectum.

The usual mixture employed consist of 75 per cent. of ether with 25 per cent. of olive oil. This method is relatively new and is

generally believed to involve greater danger than other methods and therefore should be used only in emergency and then only by those of large experience.

SPINAL ANESTHESIA

This type of anesthesia is brought about by the injection of a special anesthetic, such as solutions of procaine (novocaine), tropacocaine, stovaine, apothesine, or alypin, directly into the spinal column where resides the cerebrospinal fluid.

The effect is ordinarily that of rendering the patient insensible to pain and incapable of motion, but with a retention of consciousness. The latter fact is sometimes objectionable and as the period of anesthesia is for only about one hour a long operation may later require the administration of ether.

This method is much more extensively employed in Europe than in America and has uses and advantages under special conditions.

GENERAL ANESTHESIA BY INTRAVENOUS INJECTION

Chlorbutanol, chemically Trichlortertiarybutylalcohol, also sold as chloretone, has been used by injection, especially in experimental animals, for the production of general anesthesia. Its chief use, however, is as a preservative for hypodermic solution and its solutions as local anesthetics.

A drug of the barbituric acid group, sold as sodium amytal, chemically sodium iso-amylethyl barbiturate, seems to promise a revolution in general anesthesia. By the method most frequently employed, a solution of this drug, in carefully calculated dose, is injected directly into the vein while the patient is still in bed and before the needle is withdrawn the patient will have lapsed into complete unconsciousness and will remain so for a number of hours, thus avoiding the mental and nervous strain of preparation for ether anesthesia, the unpleasantness of inhalation administration and the early postoperative conditions so often distressing and dangerous.

The method has not been used sufficiently to know its full adaptability, but its development is looked upon by many as a distinct contribution to the practice of anesthesia.

Magnesium sulphate in 4 per cent. solution has also been used for producing general anesthesia when injected into the veins, as much as 300 cc. being used, but it cannot be accepted as an anesthetic of proven value for ordinary purposes.

THEORIES EXPLAINING ANESTHESIA

Many studies have been made in attempts to explain the action of anesthetics but no positive conclusions have been accepted. Meyer and Overton independently called attention to the fact that substances, almost without exception, which produce narcotic, sedative or anesthetic action are soluble in liquids, or fatty bodies, and also soluble in water. Reicher suggested that the liquids are washed out of the brain.

Nernst suggested the theory that as cell stimulation is brought about by sudden changes in the electric potential of a cell, due to the concentration of ions at its surface, and as anesthetics would alter the liquid at the surface of the cell, that this might explain the phenomena.

Still another theory invoves the removal of the liquid at the cell's surface with a consequent reduction in the surface tension as the fat is dissolved, with a consequent lessening of cell function. In 1911, Vesworn suggested that the presence of anesthetics would likely change the rate of oxidation in exposed cells and thus bring about a condition of asphyxia. None of these theories, however, are entirely satisfactory as explanations, although it is generally accepted that anesthesia brings about a chemical change in the protoplasm of the cell.

ANALGESIA IN CHILDBIRTH

To relieve the intense pain of childbirth has been one of the aims of the obstetrician. Probably the most frequently employed method is the administration of a small amount of ether by inhalation at the critical moment, to partially relieve the mother of suffering, but this is used with caution and only when the pains seems unbearable lest it may cause too great muscular relaxation.

A few years ago much publicity was given to a method for which was promised a complete relief from pain in labor—it was called "twilight sleep" and was found to consist of an injection of a mixture of two alkaloids, scopolamine and morphine. Unfortunately, the promises did not materialize, for, while it does relieve the pain, it was found that these drugs must be used with extreme caution since they often cause most undesirable symptoms both in the mother and newly born infant, sometimes fatal to either or both. It should only be used in special cases.

More recently, it has been found that a mixture of ether, alcohol, quinine, hydrobromide and mineral oil, injected into the rectum by what is known as the Gwathmey method is giving genuine relief.

Still another method of great promise is the use of the substance sold as sodium amytal (sodium iso-amylethyl barbiturate) which is still in an experimental stage but is of great promise for administration, preferably by rectum, to obstetorical patients.

LOCAL ANESTHETICS

Conditions often arise when a local inflamation or infection calls for treatment or operation and it is not desirable to induce complete or general anesthesia. Perhaps a tooth is to be extracted, a boil opened, or some other minor operation necessitated. Here the local anesthetic often finds a very useful application. Aconitine, veratrine, menthol, and a few other substances have long been known to exercise a benumbing action upon the nerve endings when applied locally, but this has never been a complete anesthesia. However, when Koller in 1884 demonstrated the affect of injecting a weak solution of the alkaloid cocaine, directly into the tissues surrounding an area to be treated, he opened a new era for surgery, since this injection produced complete insensibility to pain in the local area. Cocaine is the active constituent of the Coca leaf, that remarkable drug from South America which was found by the Spaniards to be in use by the natives as they climbed the Andes or were subjected to long and arduous tasks. The mere chewing of a few leaves of coca seemed to render them insensible to fatigue or hunger, the Indian often going for days without other food. Such an unheard of virtue called for investigation and the alkaloid was discovered with its remarkable qualities.

Unfortunately with its commendable qualties cocaine was soon found to possess others which counter-balanced its merits and made necessary its rigid control. The danger of its producing addicts who suffered severe physiologic reactions is today universally recognized and its sale and use limited by law to the necessities of the physician.

A study of the chemistry of cocaine shows it to be benzoyl-methyl-ecgonine and the organic chemist, working from this as a nucleus or suggestion, has produced a number of closely related synthetic compounds some of which are equally efficient as anesthetics but are not habit forming.

Among the most important of these cocaine substitutes is Procaine (Novocaine) which is chemically an amino benzol and exerts

a paralyzing action on all nerve tissue if in proper concentration. Solutions of from 0.1 to 2 per cent. strength are used and may be sterilized by boiling without decomposition.

Numerous other drugs for the same purpose have been developed among them being Tropacocaine, Stovaine, Eucaine, Alypin, Apothesin, Butyn, Holocaine and Tutocaine. Time will not permit a detailed description of these, but they all belong to this class of compounds, although they have varying degrees of toxicity and solubility and each must be subjected to a careful study to determine its specific adaptability to the conditions under consideration. A special form of local anesthesia is called for in that intensely painful disease known as "Tic douloureux" which is a neuralgia of the fifth nerve, located in the face. In this treatment alcohol is injected into the nerve ganglia, passing the needle between the last two molars, produces a relatively permanent paralysis of this nerve and relieves the pain.

LOCAL ANESTHESIA BY REFRIGERATION

Insensibility to pain has been produced through the numbing of tissue by refrigeration. This method is limited in application and in the area to be anesthetized, through the danger of permanent injury to the body cells should these be frozen. If only a small field of operation is involved, one of several methods may be employed to render the part less sensitive, but always with great care to avoid excess freezing. The most common practice is to spray ethyl chloride upon the skin until the part is well chilled and then to operate quickly. Ethyl chloride is a very volatile liquid, marketed in hermetically sealed glass tubes which are fitted with a valve and nozzle from which a fine spray may be projected at will upon the skin. As this liquid quickly volatilizes it absorbs the necessary heat from the skin and this produces an intense cold. Ether vapor has been similarly used, also ice and more recently "carbon dioxide snow," better known as "dry ice."

The latter, however, requires extreme care less over refrigeration results.

ANALGESICS OR ANODYNES

Many persons suffer periodically from intense pain in some localized area and refer to the condition perhaps as "headache" or neuralgia. This sometimes becomes very distressing and relief is often sought by the use of what is known as an analgesic, a term meaning painlessness.

Among the older drugs of this class are aconite and its alkaloid aconitine which act as depressants for the sensory nerves when applied locally over the affected area.

However, a new group of drugs have come into use in this field during the last forty years with the development of the chemistry of coal tar synthetics, and these today are extensively used under the direction of physicians and also as a household remedy.

Their indiscriminate use, however, for the relief of pain is not without danger although the names antipyrine, acetanilid, acetphenetidin (also known as phenacetin) and amidopyrine are well known representatives of this group. Their use, however, by the laity, without judgment or control, is dangerous as they are heart depressants and tend to develop a habit.

KNOCK-OUT DROPS

The anesthetic in one or more of its forms has played an important part in crime, whether actual or fictitious. The effectiveness of an attack by knockout drops is doubtless often exaggerated, especially in modern fiction when the beautiful girl is thrown into a stupor by the mere passing of a dope-saturated handkerchief over her face. However, in the annals of real crime only too often the victim has been lured by curiosity or excitement into the hands of a gang who usually offer drinks and cards and at the critical moment add to the liquor a few drops of a potent knockout agent and the victim knows no more for hours, if he ever wakes up, and in the meanwhile the gang have "cleaned him out." It may be remembered by some that this was the defence of Evelyn Thaw when she was involved in the famous Thaw-White murder case. She claimed that she was given a few drops of dope in a drink and was unconscious for hours.

There can be no question of the possibility of such a happening and only too often such "drugging" has been fatal since the administration is ignorantly done and by those who have no thought beyond the immediate effect and their get away

ELECTRICITY

One theory, among the most recent and already mentioned, explains anesthesia by showing that there is an alteration in the electric conductivity of cell membrane.

In its application experimentally a rapidly interrupted (6000 to 7000 times per minute) direct current is used and an analgesia produced which permits of minor operations without pain, although the

patient remained fully conscious. This method, however, has possibilities which further experience may prove to be of great value.

It has also been used with success in overcoming insomnia, producing what has been called "electric sleep."

THE MORE IMPORTANT BOOKS CONSULTED WERE

Anaesthetics and Their Administration, by Frederic W. Hewitt.

The Influence of Anesthesia in the Surgery of the Nineteenth Century, by J. Collins Warren.

Anesthetics in Practice and Theory, by Bloomfield.

Pharmaco-Therapeutics, by Cohen-Githens.

The Art of Anesthesia, by Flagg.

Text Book on Surgery, by Babcock.

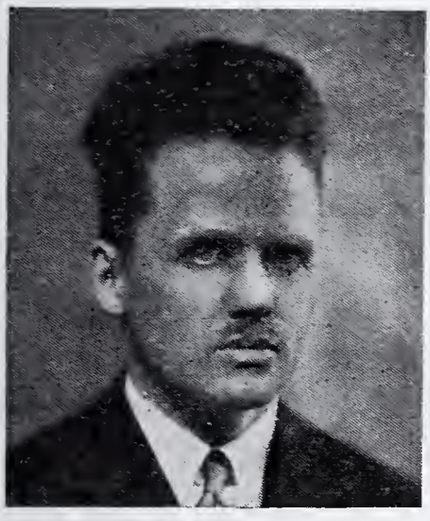
HEAT AND COLD

By Adley B. Nichols, Ph. G., Phar. D., B. Sc.

Assistant Professor of Operative Pharmacy, Philadelphia College of Pharmacy and Science.

AT THE OUTSET, let us correct our title, or correct the common idea that heat and cold are two distinct entities, for this is wrong. There is only one true unit of measurement, that is, upward from absolute zero, of which we will hear more later. Cold is merely a word used to designate the relative condition of a substance when it has less than the normal intensity of heat. To render a body cold, we do not add cold to it but we take the heat away. Heat is a relative matter for we might take a container of liquid air at 320 degrees below zero and find it would boil on a cake of ice and even more actively if a piece of ice were placed in it. To us the ice is cold but in terms of the liquid air it is hot. Heat and cold are usually reckoned by our sense of touch—c o l d—cool—warm—warmer—hot and so on, but the sensation we have is dependent on the conductivity of the article we touch. For instance, in a cold room where we know that all items must have the same actual temperature, we walk on a soft rug and it feels warm to our feet, but we step off onto the hardwood, or, more strikingly, a tile floor, and we react immediately to the change, saying that the tiles are much colder than the rug. Or we touch the papered wall and next a glass door knob, then a steel grate, and our reactions are the same, each in turn feels colder, but why? It is a matter of conduction, the ability of an article to conduct heat from our bodies when in contact with it. We all know that a teaspoon in a cup of hot tea becomes hot itself very quickly. It is a good conductor, while we could take a stick of wood, light one end of it, and hold the other end in our hand until the entire piece was nearly consumed before we would feel the heat. In other words, the wood conducts the heat very poorly. It is then the action of the good conductor taking heat

WHAT IS IT?



Adley B. Nichols, Ph. G.

from our hand when we touch it that makes the article feel cold to the touch.

Heat is generally considered as the state or condition of molecular vibration, or the violent agitation of molecules of matter. Matter is composed of extremely minute particles called molecules, which however have definite size and weight for each definite substance. It has been estimated that the molecule of water has a diameter of about one forty millionth of an inch. Though these molecules are small in size, their velocity, even at ordinary temperatures is very great. In air, in which the molecules dart about in straight lines until they encounter other molecules, they attain a speed of 1470 feet per second even at freezing temperature. The average length of their path between two encounters is about 1/277,000 inches and the number of molecules in a cubic inch of air is 443 million, million, million, thus each molecule experiences about 5,000,000,000 collisions a second and one wonders from this if they are forced to carry compulsory accident insurance. As heat is applied to a substance, these molecules expand, increase their speed and their vibration, and the greater their activity, the greater the temperature. Temperature may therefore be considered as the intensity of heat or may be thought of as the pressure of the heat in a body just as a steam gauge records the pressure and not the total quantity or volume of steam. Our teaspoon in the cup of hot tea finds its molecules at the tip of the spoon set in motion and this motion is passed on and on eventually reaching the far end of the spoon. Agitation of a substance speeds up vibration of the molecules and produces heat. We have all probably experienced this in attempting to break a soft wire in two by bending it, or have found a nail become greatly heated by being hammered. Thus heat is found in all forms of energy and may be regarded as the basic energy and all energy may be measured in terms of heat.

When one goes out on a cold day and is not dressed warmly enough, the cold stimulates the skin. The nerves then convey this stimulus to the brain and impulses are sent out which cause you to shiver. Shivering is muscular work solely for the purpose of producing heat. In order to stop it, we substitute some other muscular activity and walk briskly or run, or perhaps we turn back for heavier clothing which is to keep in the heat of the body, and not, as we often think, to keep the cold out. More food is required if we do not use the heavy clothing and exercise heavily.

SOURCE

While we may consider several sources of heat, the sun is directly or indirectly our source of supply. It is generally considered that the sun has a surface heat of from 10,000 to 15,000 degrees F. and gives out annually some 120,000,000,000 tons of heat. This of course goes out in all directions and our earth only receives about 1/2,000,000,000 part of this enormous supply. The rest goes to other planets like ours or passes off into space. The heat of the sun on our lakes, rivers and oceans takes up water, carries it over the land, clouds are formed, and the moisture is dropped to earth where it cares for vegetation, which in turn makes animal life possible, or produces coal and peat after millions of years. Brooks and rivers are again formed and by harnessing these man obtains electricity and mechanical power and energy, and so the endless chain goes on. The sun's rays have been harnessed in many ways and have been made to run boilers in Egypt and Texas and bake ovens have been prepared in a similar manner.

The internal heat of the earth produces another most interesting question, and it has frequently been suggested that the day will come when man will harness the enormous amount of heat and energy encased in this globe of ours and have it do all his work. The actual temperature of the center of the earth is only a matter of conjecture of course, for man has barely been able to prick through the skin so to speak. Our present knowledge and calculations have been made either at the natural open pits such as volcanoes and the pits in our own Yellowstone, where it would seem that something very interesting must be very near the surface, or through the deep mine shafts which have been sunk in various parts of the world. Based on the average rise of temperature in deep wells about 10 degrees F. in fifty-five feet the earth's center would be 443,000 degrees F. which is ridiculous for the sun is only 10,000 to 15,000 degrees F. and that is outside temperature. In South Dakota the temperature is found to increase 10 degrees F. in every forty-five feet and in one of the world's deepest wells in California at 8000 feet a temperature of 230 degrees F. is recorded or 18 degrees above the boiling point of water. According to these calculations we are indeed skating on thin ice and twenty to thirty miles would certainly produce something interesting. However hot the center of the earth is, the crust which surrounds it to a depth of supposedly sixty miles together with a rocky layer beneath of 800 miles, prevents this heat from escaping to any appreciable degree. After this double layer there is sup-

posedly a central core of 3000 miles composed of iron and nickel and this is calculated to be within the molten state which might be somewhat under 3000 degrees F.

Another theory of the temperature increase in the earth's crust is that it is not necessarily due to the internal heat of the earth, but to radio activity, chemical activity and so on, again bringing to mind our reference to the activity of the molecules in producing heat and energy.

TRANSMISSION OF HEAT

Heat is transmitted by one of three agencies—conduction, convection or radiation. Conduction is that agency which is propagated along its own molecules such as we had in the case of our teaspoon. As we noticed in the case of the spoon and the stick of wood we find a great difference between this conduction power in various solid bodies. Liquids are poor conductors, as we can observe by heating water from the top until it actively boils while the bottom of the container will be quite cold. And finally, gases are the poorest conductors of all. By convection, we mean that power by which heat is carried and distributed through the mass of a fluid body by the actual motion of its own particles, as in the heating of water, or as the air at the top of a room is heated by the ascending currents of warm air. And thirdly we have radiation, by which energy is transferred by etherial waves or vibration and does not depend on the presence of matter, not even air, as is instanced in the radiation of the heat from the sun to the earth through vacuum. These radiated waves are not deflected from their course by air currents, or winds. Possibly you have been forcibly impressed with the advertising medium used for radiant electric heaters, when as you are walking down the street you suddenly pass an intensely hot beam and turn to find a heater focused directly across your path through a store window. No matter how windy the day or how cold, the heat waves are still there. We see the sun's rays shining brightly through a window, but we must be directly in those waves to feel the heat. These waves of radiant energy are not converted into heat until intercepted by some material body. Black objects are recognized as good absorbers of heat and later we shall see that this principle is used in measuring heat. However, good absorbers are good radiators and where we have hot objects like stoves and steam pipes, we find they lose much of their heat by radiation and the blacker the object the more it will lose—therefore stoves and

steam pipes should be black if they are intended to give out heat, but hot air pipes, cooking utensils, etc., should be bright, tinned or nickled, in order to lose as little heat as possible. For kettles on a gas stove, however, it makes little difference whether they are bright or black as heat comes to them by direct contact with the hot gas. Accordingly, radiators in our homes would be more serviceable if they were black or at least not the usual silver finish which is generally found.

Climate or weather is really not much more than a story of heat in varying forms, for winds, storms, and daily temperatures at all times of year are the direct result of heat. Radiated waves from the sun strike the earth, cause convection currents which pick up moisture, transforming it later into clouds as cooler upper currents are reached, the clouds break and we have our rain or snow as the season may prescribe. We have our hot days of summer and our cold days of winter, which to us are enormous extremes, but are they?

ABSOLUTE ZERO

Referring for a moment to our explanation of heat as a motion of molecules, we recall that the greater the motion the greater the heat developed. Conversely, the slower the motion the less heat, and if there were no motion, there would be no heat. One of the effects of heat is to expand a body and likwise when heat is taken away contraction occurs. It is found that when a perfect gas, when confined in a vessel at 0 degree C. is cooled 1 degree C., its pressure is observed to decrease 1/273 of the pressure at 0 degree. Therefore if the temperature were lowered 273 degrees C. below 0 degree C. there would be no pressure exerted by the molecules, in other words no motion and consequently there would be an absence of all heat. This point is known as absolute zero as compared with 0 degree C. and 0 degree F. of which we will hear more later. On the F. scale, absolute zero would be at —459.60. Now then, when we consider this scale we find the surprising fact that we live and exist in temperatures barely above the bottom of the scale. Our Philadelphia temperature rarely reaches 0 degree F. on the one hand, or does it often exceed 100 degrees, the actual extremes of the weather bureau being 6 degrees below zero in 1899 and 106 degrees in 1918. The coldest temperature produced by nature was recorded in Siberia at 92 degrees below zero, while the highest on record was in northern Africa at 136.4 degrees. Yet extreme as these seem to be to us they only represent

a range from about 368 degrees to 596 degrees above absolute zero, while the sun looks down on us with an external temperature of about 15,000 degrees and an internal temperature calculated at some 50,000 degrees, and other stars range upwards of 1,000,000 degrees which must be much hotter than that proverbial orthodox abode of the morally condemned.

Balloon flights above the earth have shown extreme degrees of cold, the record being approximately 71 degrees below zero and at about seven miles the temperature apparently remains constant or increases irregularly above that point for some distance. Recent tests made in France raise the question as to whether at about twenty to thirty miles above the earth the temperature may not be 212 degrees F. or the temperature of boiling water.

MAN-MADE EXTREMES

While nature's temperatures come within a narrow range, man himself has been able to produce some very interesting extremes. Pressure we find develops heat, as anyone who has pumped up a flat tire can verify, and conversely the release of that pressure produces the opposite or a cooling effect. We find this reaction taken advantage of in our present-day refrigeration systems whereby ammonia gas for instance is alternately compressed and released with a result that brines on the exterior of the pipes carrying the released gas are chilled and refrigeration is produced. The latest and increasingly popular application of this principle is found in the making of "dry ice" as it is called. This is simply a case of releasing carbon dioxide gas from a cylinder under high pressure, into a suitable container to collect the snow that immediately forms. The temperature of this snow, or "dry ice," is about 109 degrees below zero which accounts for the "rock-like" bricks of ice cream we sometimes find packed in dry ice, while the ordinary temperature for ice cream is only a few degrees below zero.

Scientists are carrying out this principle in low temperature laboratories to even greater extremes, the low temperature laboratory of the Bureau of Standards at Washington having produced liquid hydrogen at 430 degrees below zero while at Leyden, Holland, not only liquid helium has been produced at a temperature of 458 degrees below zero, but this liquid has just recently been solidified under a pressure of 150 atmospheres. This temperature is within one and one-half degrees of the absolute zero and the work is most exacting

as materials must be purified and repurified to the highest degree and even then there are hundreds of possible causes for the interruption of the experiment.

Near this absolute zero strange things occur. All the ideas of electrical resistance are upset. Metals which because of high resistance are poor conductors become excellent ones when placed in a bath of liquid helium. In a ring of pure lead connected to a current of electricity, the charge passed around the ring and continued to do so long after the wires were removed, and would have lasted for several years, if the supply of helium could have been maintained.

What this temperature might do to us is left entirely to the imagination but there are possibilities, as shown several years ago when liquefied air was first discovered. One New York doctor had a cold well in which patients were entirely immersed except for the head, at a temperature of from 110 to 160 degrees below zero for varying lengths of time, and by this means he was able to remove cancer, bunions, corns, warts and superfluous hair, while another doctor lost chronic indigestion by the treatment.

The question as to whether life could exist at absolute zero or in its vicinity is an open one of course but we know that various forms of low animal life are now able to exist at extremely low temperatures. A fish for example may be frozen alive and restored to normal without injury and it is reasonable to assume that a fish could be subjected to the extreme cold of liquid air, but in the restoration to a normal condition the thawing would have to be very slow, otherwise the fish would burst to pieces.

Man has also reached many high temperatures the highest probably being in the nature of an artificial star, through a most fascinating experiment conducted at the Mt. Wilson Observatory. This was accomplished by exploding extremely fine wires by a powerful electric discharge. The wires, finer than a hair and several inches long, were placed in a circuit with a large condenser which was heavily charged. The circuit was closed and enormous power passed through the wire, just as though the whole power output of a generating system big enough to light a city was concentrated into the wire. There was a blinding flash and a loud report of ear-piercing sharpness and the wire was gone—not even dust remaining. That is all that could be seen by the observer, but by photographing the explosion reflected in a rapidly revolving mirror, it was found that the wire was almost instantaneously converted into a thin filament of incandescent vapor

which expanded in all directions until it had swollen to the diameter of an inch or so and then disappeared. This process took perhaps 1/25,000 of a second and calculations based on the known properties of the iron wire showed that it melted in about one-quarter of a millionth of a second, began to boil in the next one-quarter and was completely evaporated before 1/1,000,000 of a second had passed. The vapor at this time would have had a temperature of nearly 3000 degrees exerting a pressure of about one-half ton per square inch. Such a mass would then be ionized and would conduct the current from the condenser discharge and therefore become still hotter. How hot is the question, but this could probably best be determined by the amount of light it gave out, which showed it to be brighter than the sun itself, at least 20,000 degrees C. to 36,000 degrees F. Experiments such as these are made in calculating the conditions of the stars as shown by photographic records.

A temperature of 7677 degrees F. was recently attained by English scientists with a combination of manufactured gas and oxygen.

These temperatures may be more thoroughly appreciated when we make comparisons with such general temperatures as the boiling point of water at 212 degrees F., the melting point of lead at 600 degrees F., the dull red heat at 1175 degrees F., the oxyacetylene flame at 5072 degrees F. and the electric arc at 6300 degrees F.

BODY REACTION TO HEAT

Let us now look into the reaction of our bodies to heat. Normally, body heat for man ranges from 97 to 100 degrees F. with the average of 98.6 which is the figure usually taken as normal, although this varies in individuals and also varies with age. This uniform temperature of the human body is controlled by a most marvelous mechanism and all practically automatically as far as any thought on our part is concerned. The food we eat is changed by combustion into heat just as similar combustion changes coal into heat for our homes. Our muscles by their action are constantly producing heat. The heart and respiratory organs are likewise producing their share by their continuous action. All this heat in a normal properly functioning body is lost as soon as it is produced and thus our body temperature remains unchanged. The harder we work, the more action we give our muscles, the more heat is produced and this is automatically given off as fast as it is produced. This same thing occurs in boiling water for water boils at 212 degrees F. and no matter how much

heat we apply after it begins to boil, it becomes no hotter, but the extra heat is given off by the actual boiling. The body loses about three-quarters of its heat through the skin by conduction, convention, radiation and perspiration, while most of the balance is lost through the action of the lungs. No matter whether one is with Byrd at the South Pole, or in the middle of the Sahara, the thermostat functions perfectly, closing the pores to retain the heat in one case or opening them wide to eliminate the excess in the other, just as we open and close the dampers on our furnaces in our homes to get the same effect from them. Is there another instrument anywhere so delicate and so constant, able to give control under such extreme odds? Naturally, such a mechanism must be protected. Total prevention of respiration through the skin would result in complete collapse, as happened years ago during a religious fete in Italy where a child was covered from head to foot with gold leaf to represent an angel. In a few hours the child was dead, people interpreting the case at that time as one of divine displeasure, but today we know that a modern doctor would have scraped off the gold leaf and saved the child's life.

The opposite effect of too little evaporation and loss of heat from the skin is also found. In hot weather more heat may go to the body than it is able to give off, particularly in the case of high temperature and also high wind which keeps the skin perpetually dry and allows body temperature to rise to a point where it endangers life. That is why we usually find dry skin a forerunner of sunstroke. Then again, cool the body one degree or so below its normal temperature and a sense of chill is immediately manifest, the system reacting and shutting off perspiration. Extended loss of heat depresses the tissues so that death results. What is called "death from exposure" is really due to heat loss. An underfed, poorly clothed and perhaps intoxicated person falls asleep out of doors in a frosty night; so much heat is lost that the heart and nervous system never recover and the person never wakes. The lowest temperature recorded in man, 80 degrees F., has been under such conditions.

FEVER

When the body is unable to regulate its own temperature within fairly narrow limits the body machine is usually in need of repairs of some sort. When the temperature of our automobile engine reaches a point abnormally high we know that there is something wrong with the water or oil cir-

culation. When the body temperature is raised, the blood circulation may bring about the same conditions and very often the individual loses his bearings too.

As someone recently wrote on this subject. "We often want to be someone else, but only mentally deranged become that.

"However, with fever of 102 we become someone else but not the one we always hoped to be. This fever person is forced on us, not chosen. He is not superior to the normal self but inferior—he is quite different than the normal self.

"Good and evil is a matter of total indifference to him. He doesn't care whether he is rich or poor, no hatreds disturb him—Those who were his loved ones are strangers now—His enemies are neither more or less—News of his ruin or death of his friends does not disturb him for every time there is a rise in temperature life becomes less interesting and death less terrifying and actually comforting."

We may place 111 degrees F. as the highest internal temperature compatible with life. At this temperature permanent injury is certain because the nerve cells are definitely changed by heat coagulation at about 110 degrees F. and the heart probably fails at about 108 degrees to 109 degrees F.

Of course external temperatures are quite another thing. Experiments have shown that man is able to withstand temperatures of 250 degrees F. for fifteen minutes without ill effects or serious rise in body temperature, while a steak exposed to the same environment was cooked in thirteen minutes. At first thought we might conclude from that that as a delicacy for a pack of cannibals we would be rather tough, but it must be remembered that the ability of the human body to withstand this high temperature depends on the efficiency of the body in keeping cool by evaporation, a feature also enjoyed by the steak when it was a cow grazing in the sun.

HUMIDITY

We cannot pass this phase of our subject without consideration of another very important angle. The question of whether or not it is hot enough for us is not entirely one of temperature as indicated by the thermometer, for in Philadelphia for instance we would undoubtedly say, "Yes, too much so," while one from the southwest would tell you that there was no special discomfort and no wilted white collars at 110 degrees in the shade, and yet both would be right. Cold enough and only at 32

degrees or so would bring forth the same answer from the east, while one from Montana will tell of not suffering at 25 degrees below zero.

"NOT THE HEAT—THE HUMIDITY!"

The answer lies in the condition of the air known as relative humidity, something that is rather vague to most of us because there is no simple method of measuring it, while on the other hand we find thermometers everywhere.

As a matter of fact desert air in Arizona may contain as much water vapor as that in Philadelphia, but at the higher temperature it does not make itself known. When air is saturated with water vapor we find it extremely oppressive, particularly at high temperatures. Air at the same temperature but with only one-quarter the amount of water would be most delightful and exhilarating. Denver, Colorado, is considered as a summer resort and Washington, D. C., anything but that, and yet the two temperatures are about the same, but Denver has a relative humidity of 52 per cent. in August while Washington has 77 per cent. relative humidity meaning the ratio of total moisture in the air compared to what it could actually hold at that temperature or the saturation point.

As the cooling ability of the body depends on evaporation to be effective, when relative humidity is low, perspiration evaporates rapidly and the body readily cools to the proper temperature. When relative humidity is high, the air is near the saturation point for water vapor and perspiration collects on the skin and dries slowly, if at all, and we speak of the weather as sticky.

In cold weather high relative humidity is again disagreeable, this time because moisture penetrates the clothing and makes it a better conductor of heat, with the result that the body cools faster and we say the cold is penetrating and we are chilled to the bone.

This humidity question enters our homes, too, and is responsible for much of our winter sickness, colds, catarrh, bronchitis, chapped hands and face, etc. When our rooms are dry, the mucous membranes of our noses and throats become dry and parched and splendid opportunity is given to the germs of cold and influenza to take hold. Heat greatly increases the capacity of a given space for water vapor. For instance, it requires about four times as much water to saturate the air at 70 degrees as it does at 30 degrees and increasing the temperature from 70 degrees to 80 degrees increases

its capacity for moisture about 50 per cent. Superheating, therefore, is very objectionable and actually dangerous. It is quite a task to supply the necessary water vapor to give the best results, but the problem can best be solved by maintaining lower temperatures. Instruments for determining this relative humidity will be discussed later but we might mention here that a temperature of 68 degrees F. with a relative humidity of 50 per cent. is not difficult to approach in the home where plants, radiator pans, wet towels, etc., may be used to give the desired moisture and the reaction one attains from such a combination is very invigorating. We must not consider this 68 degrees in the same terms as we have probably been accustomed to consider it for we find it is not cold, as we have supposed, when the humidity has been properly controlled in connection with it. Dry air and high temperatures definitely tend to nervousness and restlessness, inability to concentrate, irritability, drowsiness, loss of appetite, low spirits and lower body resistance, while a lower temperature with controlled humidity eliminates all of these and we are exhilarated and enjoy our work, our play and our leisure hours to the fullest extent, at the same time raising our health level to a much higher degree.

Further references might readily be made to this question and the many uses to which it is placed in practice but this subject will undoubtedly be thoroughly covered in one of the lectures soon to follow in this series.

NEED FOR TEMPERATURE MEASUREMENT

Let us now turn our attention to the methods of measuring the degree of heat or temperature, and the many and varied instruments with which this is done. We might first look into the question of why it is necessary to measure temperatures, in other words the application of heat to our daily lives.

THE HUMAN BODY THERMOSTAT

We have already considered the temperature of the human body and have discovered what happens when the normal body temperature fluctuates. There is surely no need to go further into that question for we all know how the doctor watches the temperature chart which tells the story of the sick one so vividly. He has long ago given up the old idea of trying to determine temperature by placing his hand on the patient's forehead.

WHY THE WEATHER?

We have also mentioned the weather which we found to be controlled primarily by heat. And is there anything more talked about? Is this not one place where all humanity meets on a level? The millionaire asks the milkman in the morning what the temperature was at sunrise, and the policeman forgets his duty long enough to speak of the intense heat or biting cold and so on. We have probably been discussing this question only recently and claiming that we are using more coal this winter, which may be quite true, but it is probably the fault of the coal, for actual figures show that the average temperature of the first few months of this winter were above those of last year. And over extended periods these same records show that the seasons remain pretty uniform from year to year. That our perspective in this regard changes was very nicely shown by the old timer who was discussing winters as he knew them. He remembered well, when as a boy, he had waded through snow up to his crotch, but he also realized that his crotch at that time was only about "so high."

IN THE KITCHEN

What part does temperature play in your everyday life, in your kitchen for instance? Your first thought, of course, is of your stove which is a direct means of providing heat for the room itself, or it boils water for your dishes and clothes but primarily it is used to cook your foods for your daily meals and surely you know what happens when the temperature is not controlled there. Puddings boil over, cakes burn, peas stick to the dish because the water boiled off and the heat became too severe. But even the stove itself is a product of temperature control, from the iron and steel which enters into its makeup, to the pretty green enamel, placed there by a carefully regulated baking process. The aluminum and the agate pans you use with the stove, the kitchen table with its enameled top, the china in your cupboard, the paper lining the shelves, the very shelving and the food itself from pasteurized milk to all the canned goods, are all possible and uniformly excellent because of temperature properly controlled. The California fruits in your refrigerator, the eggs certainly, the refrigerator itself, the linoleum of the floor, the curtain at the window, the electric light and the chain by which it is suspended, the wall switch and the light cords. As a matter of fact is there anything we can mention that does not link itself up defi-

nitely with temperature control? The gasoline for your automobile is obtained purely through temperature control, and is set off to propel your car by the same means. The tires your car runs on, the upholstery, windshield, chassis, and in fact every part of it is temperature controlled. The gas for your cook stove is all prepared by proper control of temperature. Your baker does not burn his bread or cakes because his ovens are properly and automatically controlled. Your milk is safe to drink because it has gone through a pasteurization process, which is just one of temperature control. Your green houses are of course under temperature control, refrigeration plants, chemical manufacture, confections, glass manufacture, paper industry, steel, cement, soap and so on, naming what you will.

Orange groves are protected today by an alarm system which tells the owner when dangerous temperatures are approaching so that he may be able to start his smudges and protect his groves.

The thermometer is being investigated now as a divining rod to locate oil deposits and certain minerals by relying on the suspected fact that the temperature rises in the vicinity of oil, coal, salt, etc.

A Kansas chemist has recently made synthetic diamonds from iron filings and sugar liquefied under a temperature of 2500 degrees C. and then plunged into ice cold salt water. And so it becomes an endless chain and one wonders what man will be doing with the temperature at his command in another hundred years.

DEVELOPMENT OF THE THERMOMETER

Almost every thermal phenomenon has been utilized for temperature measurement, from the simple expansion, normally and under pressure, of liquids, solids and gases, dissociation, fusion, ebullition, conduction, radiation, electrical resistance, acoustics, vicosity, color, specific heat, thermo-electrics, etc. The principles upon which each of these phenomena operate will be considered with the individual instruments.

Probably next to his watch man consults his thermometer as much as anything of his many and varied inventions and it rules him just as strongly as his timepiece does. It compels him to put more coal on the fire in the winter time when he finds the indicating fluid sinking too low, and in the summer it forces him into thinner and lighter raiment. Did you ever pass a thermometer without reading it? Neither did anyone else.

THE FIRST THERMOMETER

The credit for the first thermometer goes to Galileo of Padua who, in 1592, invented an instrument described as "a glass containing air and water to indicate changes and differences in temperature." It consisted of a glass tube about sixteen inches in length with a hollow bulb fitted in the end. The whole was heated until the air inside became rarified, when the open end was placed in water, the tube being kept upright. As the air in the tube and the bulb at the upper end cooled and contracted, the fluid in the tube rose to a certain point and any subsequent changes caused the level of the liquid in the tube to either be elevated or depressed, while an arbitrary scale gave a rough indi-

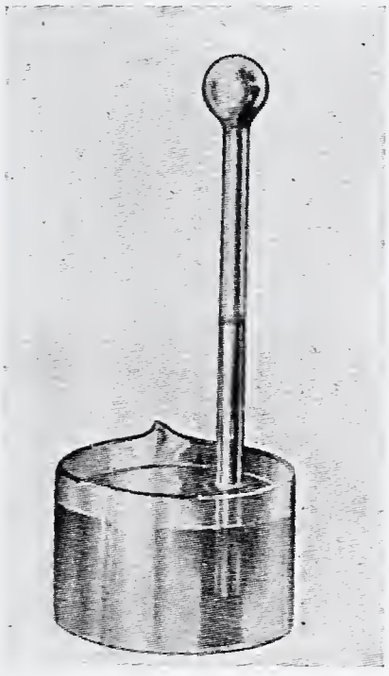


Fig. 1.

Sanctorius' Thermometer of about 1620—representative of Galileo's first thermometer.

cation of the temperature changes. Drebbel of Holland is frequently mentioned in connection with the early thermometers, but the credit for the first is generally given to Galileo.

Sanctorius, a professor and physician at Padua was the first to use this principle as a heat measure or fever thermometer in 1611. He had his patients hold the top of the tube or bulb and the raising or lowering of the liquid in the tube indicated the patient's condition.

About 1630 a French physician M. Jean Rey, made a similar thermometer but used alcohol and kept his instrument in an upright position, noting the rise and fall due to the expansion of the liquid itself and not to the enclosed air in the tube. It was shortly after this that the Grand Duke of Tuscany improved upon Galileo's thermometer and used alcohol in a sealed tube, while some of Galileo's students made a scale by melting beads of glass to their thermometer tubes to indicate points of temperature.

Later on a need was seen for a definite scale with fixed points and Newton, in 1701, prepared such a scale using the melting point of ice, the temperature of the human body, the boiling point of water, and the melting point of tin as points of reference.

THE FAHRENHEIT THERMOMETER

In 1714, several years after Newton's work, considerable advances were made by Fahrenheit of Dantzig, Holland, and it is the Fahrenheit scale that is mostly used today in temperature-indicating instruments. Many theories, all really uncertain, have been given as to the method by which he arrived at the several points of his scale, the one generally accepted as the most probable, being as follows: According to this theory Fahrenheit adopted, as the zero of his thermometer, the temperature which had been observed at Dantzig, in 1709, which he found he could always reproduce, by using a mixture of ice and salt. At that temperature (which he believed to be an absolute zero of cold) he computed that his instrument contained 11,124 equal parts of mercury, which, when plunged into melting snow, were increased to 11,156 parts. Hence the space included between these two points (viz., 11,156 —11,124 = 32) was divided into 32 equal parts, and 32 degrees indicated, therefore, the freezing point of water. When his thermometer was plunged into boiling water, Fahrenheit estimated that the mercury was expanded to 11,336 parts or 212 parts above his zero, and therefore 212 degrees (11,336 —11,124 = 212) was marked as the boiling point of that fluid. In practice, Fahrenheit determined the boiling point of water, and the melting point of ice, and then graduated the tube by equal divisions to his zero. To Fahrenheit belongs the merit of having introduced the use of mercury in thermometers, which had previously been made only with alcohol, water, or air. He also introduced cylindrical bulbs to increase sensitivity.

THE CENTIGRADE THERMOMETER

The second most popular of our present-day scales known as the Centigrade, from centum meaning one hundred and graduum meaning graduations, was devised in 1742 by Celsius, a professor of astronomy at the University of Upsala. He divided the distance between the boiling point and the freezing point of water into 100. However, his scale was inverted, the freezing point being taken as 100 and the boiling point as zero. Shortly afterwards (1743) Christin of Lyons, France, reversed these points producing the modern Centigrade scale of today.

The third thermometric scale in use today, particularly in Europe, is one made by Reaumur a French physicist in 1731. He studied the use of alcohol in a thermometer and found that a certain mixture of alcohol and water expanded from 1000 parts to 1080 parts between the freezing and the boiling points of water. Taking the freezing point of water as zero and the boiling point as 80 he divided his scale into 80 equal parts.

Thus we see the comparison of the three systems, all based on the boiling and freezing points of water, 212 degrees F., 100 degrees C. and 80 degrees R. representing the boiling points and 32 degrees F., 0 degrees C. and 0 degrees R. representing the freezing points, the zero on the F. scale being 32 degrees below the freezing point.

Several methods of obtaining the values of one scale in terms of the next are available though possibly somewhat confusing unless one pictures the three systems side by side. To eliminate confusion, let us consider conversion of C. and F. degrees only, as R. degrees are seldom used in comparison with the extensive use of the others. By following the drawings we see that $°F = (°C \times 1.8) + 32$, while $°C = (°F - 32) \div 1.8$ or by the same method but using fractions instead of decimals $°F = (°C \times \frac{9}{5}) + 32$ and $°C = (°F - 32) \times \frac{5}{9}$. Another very simple scale which eliminates the confusing 32 is as as follows:

$= (°C + 40) \times °F \frac{9}{5} - 40$, while $°C = (°F + 40) \times \frac{5}{9} - 40$.

Mercury, as the activating substance for a thermometer, has several advantages over other substances. In the first place it has a wide range, or fortunately a range which meets most general demands. It freezes at —39 degrees F. and does not boil until it reaches about 675 degrees F. under ordinary pressure. By increasing the pressure mercury thermometers are available today which will record temperatures several hundred degrees above this point. Secondly, the fact that mercury has a uniform and regular rate of

expansion is a valuable point in its favor, as many liquids may expand slowly at lower temperatures and rapidly at higher temperatures, which makes them very unsatisfactory for this purpose. In the third place, mercury does not cling to glass as other liquids do, and finally it may be easily obtained in a purified state. Being opaque it can readily be observed in fine capillaries.

MAKING A THERMOMETER

The actual making of a mercurial thermometer is a very interesting and a most exacting process if the resulting thermometer is to give accurate and consistent readings, and after following Mr. Thermometer through

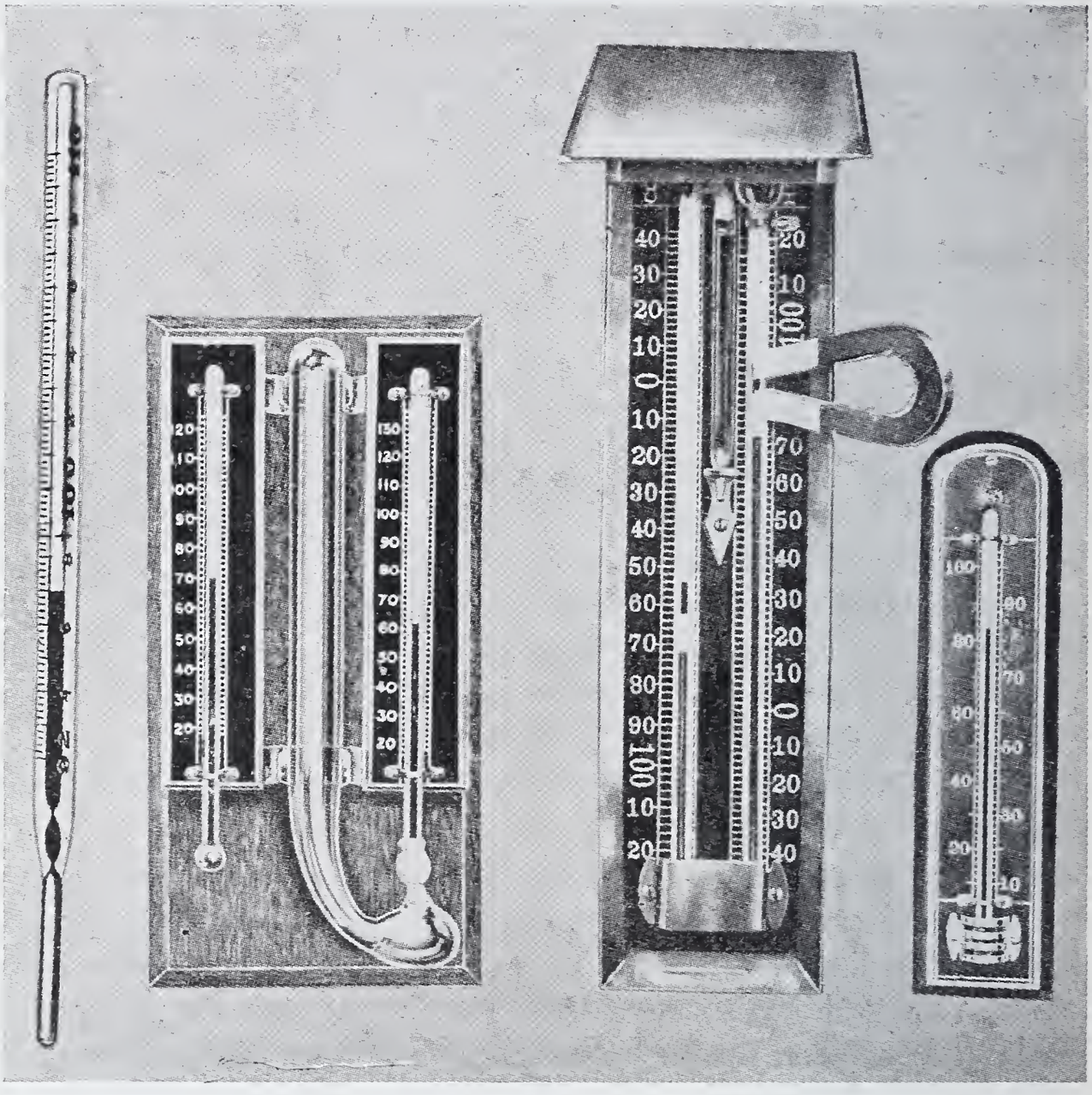


Fig. 2.

a. Clinical thermometer; b. wet and dry bulb thermometer; c. maximum and minimum temperature thermometer; d. household thermometer.

his make up we will no longer wonder why it is that "good" thermometers cannot be had at the "five and dime," but must be paid for with good cash.

In the first place, the glass used must meet very exacting demands. It must rapidly return to its normal state after exposure, for glass like most everything else, expands when heated and contracts when cooled. It must remain clear when heated and must not become clouded. Many poorer quality glasses cloud up considerably. It must not soften at the temperatures with which it is to be used, nor should it be distorted, a feature we see in most of the common window glass in our homes. It must give clear cut markings so that it can be properly graduated.

When such a glass as is required for the particular type of thermometer to be made, is found, the next step is to prepare the long capillary tube. A quantity of melted glass is taken up on a hollow pipe and a bubble is formed in the glass by blowing through the pipe. Then by manipulating the pipe the operator rolls the glass out into a cylinder, the bubble now becoming elongated with the mass of glass. The mass is then somewhat flattened, enamel glass is placed on the part of the cylinder behind the inner core or bore as it is called and the entire mass is again dipped in hot glass to cover and protect the enamel. If the tube is to be V-shaped, or lens shaped, as most clinical thermometers are, to facilitate easy reading, it is forced into a mould at this time.

One end of the cylindrical tube is then fastened down while the other end is gripped firmly and drawn upwards for about 150 feet with the result that the cylinder has been stretched out for that distance and now is in the form of a long perfect tube with an extremely fine hole in the center. This tube is then cut into convenient working lengths which are carefully sorted out according to the size and uniformity of the bore, some of which are actually finer than a human hair. This grading is done very carefully with the aid of a microscope.

These tubes are now cut to smaller lengths. One end is sealed and then after softening by a blowpipe, air is blown into the opposite end until a bubble or bulb has been formed, the size of the bulb being carefully regulated by the skilled operator so that it will function properly with the tube in question. It is at this point that the sensitivity of the thermometer is determined, as improper regulating

will give a bulb which will be all out of proportion to the bore of the tube and either give too little or too great a rise in the mercury column for accurate readings.

After the bulb has been formed to the correct size and while it is still hot, the open end of the tube is placed in pure quicksilver and upon cooling the quicksilver is drawn up into the tube. The bulb is then heated and again the tube is dipped into the mercury, repeating the operation until the bulb and tube are completely filled. The tube is then "roasted" to drive out all moisture and finally the open end is drawn out to a fine capillary, the bulb is again heated until the mercury rises in the tube and expels all the air. Finally with a blow

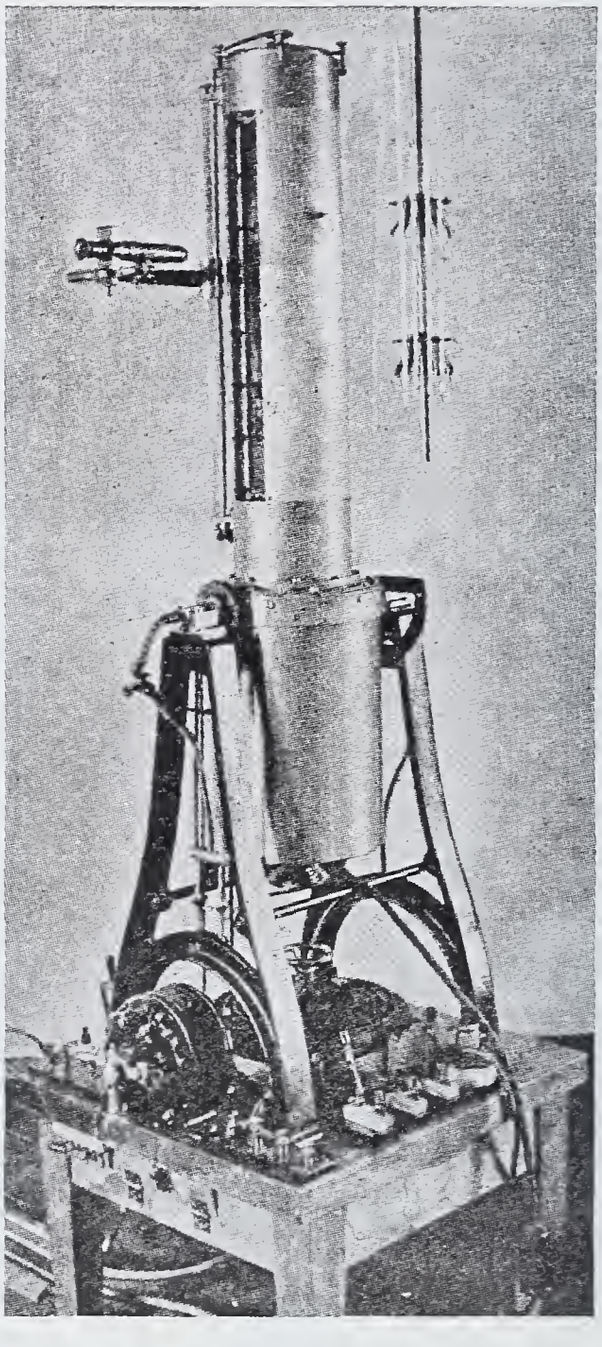


Fig. 3.

Apparatus for Testing and Calibrating Precise Thermometers.

pipe, the capillary is shut off and upon cooling the mercury again flows back to the bulb.

The next step is the graduation of the tubing. This is accomplished by placing it in baths of known temperature usually 2 degrees, 32 degrees, 62 degrees and 92 degrees F. and marking the reading on the tube in each case. If these four points are equidistant, then it is a simple matter to subdivide each section into thirty equal spaces. The tube is placed upon a brass plate and the marks which denote 2 degrees, 32 degrees, 62 degrees and 92 degrees are reproduced at exactly the same positions as they appear on the tube, after which a dividing or marking machine does the rest. Then comes the ageing for two or three years, for unless this is done, there may be considerable variation in the reaction of the glass due to shrinkage, for instance the temperature may be raised from 30 degrees to 80 degrees but when the thermometer is brought back to its original surroundings, it might only record 32 degrees instead of 30. After ageing, the thermometer is finally ready for the market.

Is it any wonder therefore that these little instruments, that *is*, good instruments, are expensive? Of course, there are cheap ones avaliable for those who desire them, thermometers made of poor glass, carelessly graduated, carelessly attached to the scale or with possibly a painted scale, bulbs which do not fit or match up with the bore of the tube which may be uneven in itself, thermometers not aged, poor quality quicksilver, etc. These are the thermometers which you look over in a case and finding that no two agree in reading finally give up in despair. Of course they would probably tell you whether it was the dead of winter or the middle of summer, but to most of us, thermometers are more useful than that.

THE CLINICAL THERMOMETER

The clinical thermometer as first originated, was about ten inches long, the short stem variety of today being originated by Clifford Allbutt in 1867. This thermometer is a short range thermometer, 95 degrees to 110 degrees F. and is a maximum type, that is, the mercury column stays at the maximum reading until it is shaken down. This provides an opportunity to obtain an accurate reading and it is accomplished by having a restriction in the bore of the tube, or a small glass hair or splint, called a "choke bore" prevents the mercury from receding. Frequently this fine glass hair is broken by shaking down a thermometer, which should therefore be handled carefully and not jarred

too severely, the proper method being to grasp the upper end of the thermometer and to describe an arc merely with a twist of the wrist. The bore and bulb of a clinical thermometer must both be very fine to give delicate readings, and with such a fine bore it would be almost impossible to read the position of the mercury without the "lens" front which is usually found and which magnifies the capillary very nicely. These thermometers are available usually as one-half, one- and two-minute instruments, which simply means that one gives quicker results than the other.

LOW-TEMPERATURE THERMOMETERS

Thermometers for temperature readings below the freezing point of mercury usually employ alcohol which does not freeze until it reaches 176 degrees below zero which is well beyond the normal call of a thermometer. To make its column readily noticeable it is colored with a dye, usually bright red. This has frequently led to the assumption that this material was red mercury and more than one call has been made for such a substance.

Beyond the range of alcohol are several liquids which have still lower freezing points, such as pentane, which will record as low as 200 or 300 below zero, or below the temperature of liquid air.

Only recently gallium, another chemical, has been used in place of mercury in a thermometer for high temperature ranges, as it will record up to 1800 degrees. Of course ordinary glass at this temperature would be unsatisfactory as it would melt, so a fused quartz tube is used to replace it.

GENERAL THERMOMETERS

However, before we leave the mercury type of thermometer, let us mention several other applications of it to everyday needs. There is, of course, the bath thermometer, often encased in a wooden block and frequently with a large hollow tube so it will float on the surface of the water. This is graduated in terms of suitable bath temperatures, such as tepid, warm, hot, etc., as well as indicating actual degrees. Baby's baths must be carefully controlled and physicians today recommend baths of definite temperatures for different ailments, a certain one being for the treatment of a cold, while another is to sooth and allay the nerves, or possibly to rest the body or relax the muscles. In other words there are many more reasons for a bath today than just the fact that it is Saturday.

The housewife also wants a thermometer for her oven, for recipes today are based on definite temperatures and with this control, burnt offerings are naturally not so frequent. She also finds that a candy thermometer graduated in terms of that art is quite an aid, replacing somewhat the old "hairing" and "hard ball in water" technique. A similar one is available for jelly-making, so there is no longer any reason for the grape mixture not to jell.

The chicken incubator also has its own specially prepared thermometer set at 103 degrees, and we all know what temperature control means there, where a variation of only a degree or two means no chicken or a cooked one.

Mercury thermometers are also prepared for measuring deep water temperatures. In order to overcome the difficulty of having the thermometer reading changed while it is being drawn up, the instrument is ingeniously made so that it is lowered upside down and at the desired temperature, a trip releases it so that mercury will act, and once it does, another arrangement prevents it from dropping back or raising higher up in the tube.

Another interesting thermometer is the maximum and minimum type. This is made in the general form of a U with a bulb on each end. The scale on one arm of the U covers the lower range of temperature, while the one on the other arm covers the upper range. In moving back and forth in the tube, a mercury column forces a fine glass capsule containing a fine piece of steel ahead of it, which remains stuck in the tube when the mercury recedes, thus indicating the maximum or minimum points reached by the mercury column. To reset the instrument, a small magnet again draws the capsule down to the mercury column.

HYGROMETER OR HUMIDITY METER

A double thermometer in which one bulb is kept moist is used to determine humidity or the amount water vapor in the air. From our previous discussion of this subject we know that the air will take up moisture to the point of saturation and the more moisture in the air the less it can take up. We also know that evaporation produces a cooling effect, and it is upon these principles that this instrument, the hygrometer, is based. The two thermometers are set up practically side by side, one being the ordinary dry bulb type while the bulb of the other is covered with a fine silk bag or wick which dips down into a cup of water. As the moisture from the bag evaporates, it pro-

duces a cooling effect on the liquid in the thermometer bulb, the faster the evaporation, the greater the cooling effect, the speed of evaporation depending on the present moisture content of the air. By taking the reading of the two bulbs and noting the difference between them, one can refer to a prepared chart which at once tells the relative percentage of moisture present in the room.

Another instrument based on this principle, is the hydrodeik. In this case a needle swings across an arc and readings are taken where certain connecting lines between wet and dry bulb temperatures coincide.

As the instruments described above do not give true readings because they may be operating in quiet air and the actual air surrounding the instrument may be nearly saturated, sling hygrometers have been devised. In these, the two thermometers are attached to a handle whereby they may be whirled about, thus obtaining the maximum cooling effect from the wet bulb. These instruments are usually spoken of as whirling psychrometers.

Instruments for recording moisture content have also been made using a hair as the controlling factor. This is based on the fact that a hair stretches when it is moistened and tightens up when it is dry, the amount of extension being calculated as 3/128 of its length in saturated air. This reaction is made to record on a scale, of course.

If you want to experiment with a unique thermometer next summer, try the vocal thermometer as indicated by the crickets. Experiments have been made to show that the chirping of a cricket is definitely linked up with the prevailing temperature. The temperature in degrees F. equals the number of chirps made in fifteen seconds plus 37 and there is about 1 degree rise for every four chirps per minute.

THERMOMETERS BASED ON OTHER PRINCIPLES

Many types of thermometers have been made in which the expansion and contraction of a gas, other than mercury, has been used. In these, the gas, in an enclosed bulb or case, comes in contact with the source of heat and expands, either pressing directly against an indicating needle or working against a mercury column or manometer which then operates the needle.

Air thermometers were in early use as scientific instruments. Princep in 1827 was the first to put this idea into actual practice. He

used a bulb of gold connected to a reservoir of olive oil which exuded as the bulb expanded, the temperature of the bulb being determined by weighing the displaced oil. Davy later used a similar device in which he replaced the oil with mercury.

Pouillet with a platinum bulb was able to reach the highest temperatures, and his work laid the basis for pyrometry of today. He took definite steps in radiation pyrometry by determining the temperatures at which solids glow, then calorimetric pyrometry by determining the specific heat of platinum and finally thermo-electric-pyrometry by calibrating a thermocouple of iron and platinum.

Displacement of one gas by a second is another important method of operation. The determination of vapor densities at higher and higher temperatures are thus made and from this all high temperature thermal measurements depend.

As far back as 1731, there were devices available based on the expansion of solids themselves, such as the single-bar device where one end of a bar is held stationary and its lengthening upon heating is read off on a scale in terms of degrees of temperature. This was followed by instruments which were based on the differential expansion of two solids, such as iron and brass for instance. These were firmly joined together and shaped into a coil, one end of which was held stationary while the other was allowed to open up or contract as the case might be, due to variations in temperature, a needle on the free end indicating the temperature.

Fusion points of metals have been of great value in determining temperatures and the melting points of some pure metals are today used as points of standard reference. Ingots of alloys, prepared to melt at various temperatures are placed in a furnace and the temperature is then indicated by the melting down of certain cones, and noting that others which have higher melting points have not been affected. Seger's cones which are used in porcelain manufacture depend on the softening of cones of clay. Holdcroft's thermoscopes, also of this type, are small bars supported at their ends and in a horizontal position. When the critical temperature is reached, the bar sags in the middle.

Specific heat has also been mentioned as a basis of action and in this we find temperature is measured calorimetrically. Iron and copper, for instance, are exposed to heat and then plunged into

water under definitely controlled conditions whereby the increase in temperature of the water may be measured. Or the hot air of a blast is cooled with a known quantity of cold air and the resulting temperature is measured.

Boiling points of liquids and solids have also been used to indicate temperatures and our question of conduction is another means of approach. A bar of iron for instance is placed in a furnace and the temperature at various parts of the bar, cool enough for measurement with a mercury thermometer are made, or water is measured before and after leaving a furnace.

Acoustics or the question of wave lengths has also been the basis of temperature measurement. This is based on the velocity of sound in dry air at different temperatures. We have all heard the screech of a swinging sign on a cold winter night or the shrill squeak of the wheels of the coal truck, sounds which we do not hear during the summer months. Compare these with known notes and record them in terms of temperature and we have a thermometer.

THERMO-ELECTRIC INSTRUMENTS

Thermoelectric instruments, or thermocouple pyrometers as they are called, offer a very interesting means of determining temperatures. These are based on the principle that an electric current is set in motion when

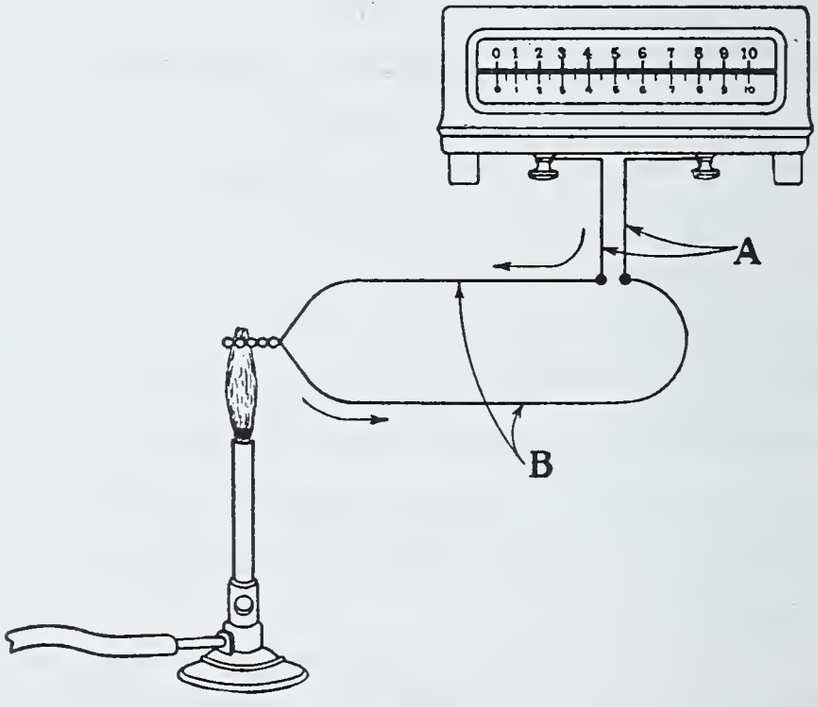


Fig. 4.

Principle of Thermo-electric Meters or Pyrometers.

two dissimilar metals are heated at their junction. These instruments cover temperature ranges from about 100 degrees upwards. They measure the temperature at this hot junction point only, consequently giving quite accurate readings and because this point is so fine, temperatures can be determined where the dimensions of the hot space scarcely exceeds a physical point. The thermal indications are instantaneous. The electric current which is set up through the fine wires of this instrument is recorded by a sensitive galvanometer which operates a needle against a temperature chart.

HEAT OF STARS

The temperature of the stars are measured by just such instruments as this. A 100-inch telescope is used to concentrate the greatest possible amount of starlight, but even this would be useless were it not for the incredible sensitiveness of the receiving apparatus. The stars rays pass through a transparent window into an exhausted receiver and fall on a tiny thermocouple. The wires of the couple are hardly more than 1/1000 of an inch in diameter and the entire couple weighs less than 1/600 of a grain, the part which is heated at any one time by the star's rays weighing only 1/2000 of a grain. The heat from the most active star, when concentrated on this tiny speck, raises its temperature less than 1/60 degrees, setting up a current of 1/7,000,000 of an ampere, but the galvanometer is so sensitive that the recording spot of light swings through an arc eighteen inches long. 1/100,000 of a degree has been measured and any star which can be seen by the naked eye can be estimated

This instrument could detect the heat of a candle 100 miles away if there were no loss due to absorption by the intervening atmosphere. Focused on a group of candles it could actually count the number in the group.

RESISTANCE THERMOMETERS

Resistance thermometers are made to cover ranges approximately from 300 below zero to 1000 degrees above. These are based on the fact that most electric conductors change their electrical resistance with variations in temperature, these changes then being measured in electrical units and automatically converted into degrees F. or C. A wheatstone

bridge is used to balance up the instrument to surrounding conditions and a bulb containing pure nickel or platinum wire is used at the source of heat. As the temperature rises the resistance of the wire in the bulb increases and this resistance is then measured by again balancing the bridge.

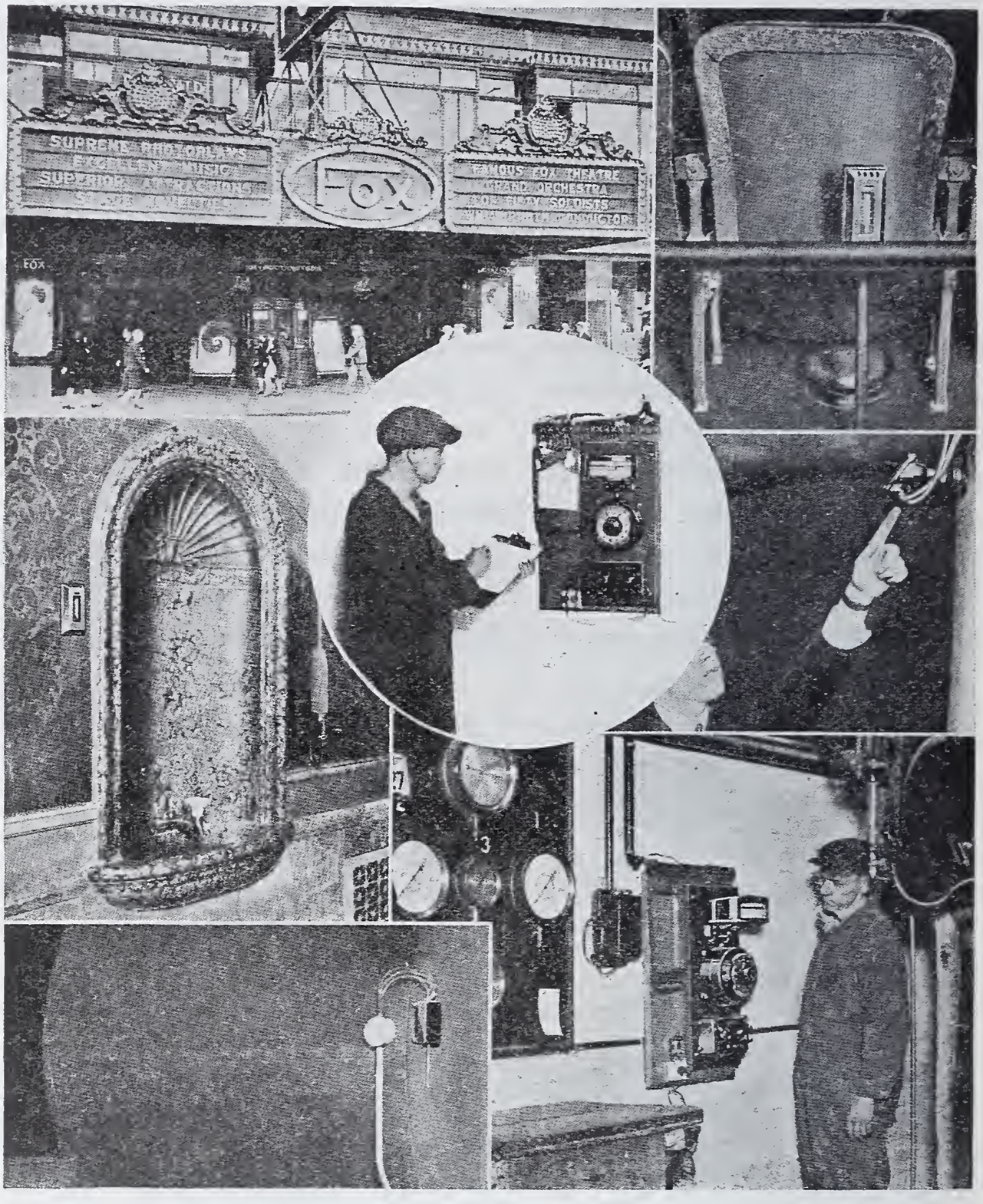


Fig. 5.

Application of Distant Recording Thermometers Showing Various Locations of Resistance Bulbs and Central Recording Station.

RADIATION THERMOMETERS

Radiation is also used as a means of measuring temperatures. Optical pyrometers are available in which the temperature is determined by matching the luminosity of a hot body with that of a calibrated source or by utilizing the visible radiation emitted from a hot body. An instrument of this type is of little use therefore on articles not heated to the point of incandescence and can be used only when the operator can directly observe the heated body. Its use begins with temperatures of about 1400 degrees. Instruments of this type are used in steel mills where the heat radiated from a furnace, for instance, is caught by a concave mirror, at the focus of which is a thermometer.

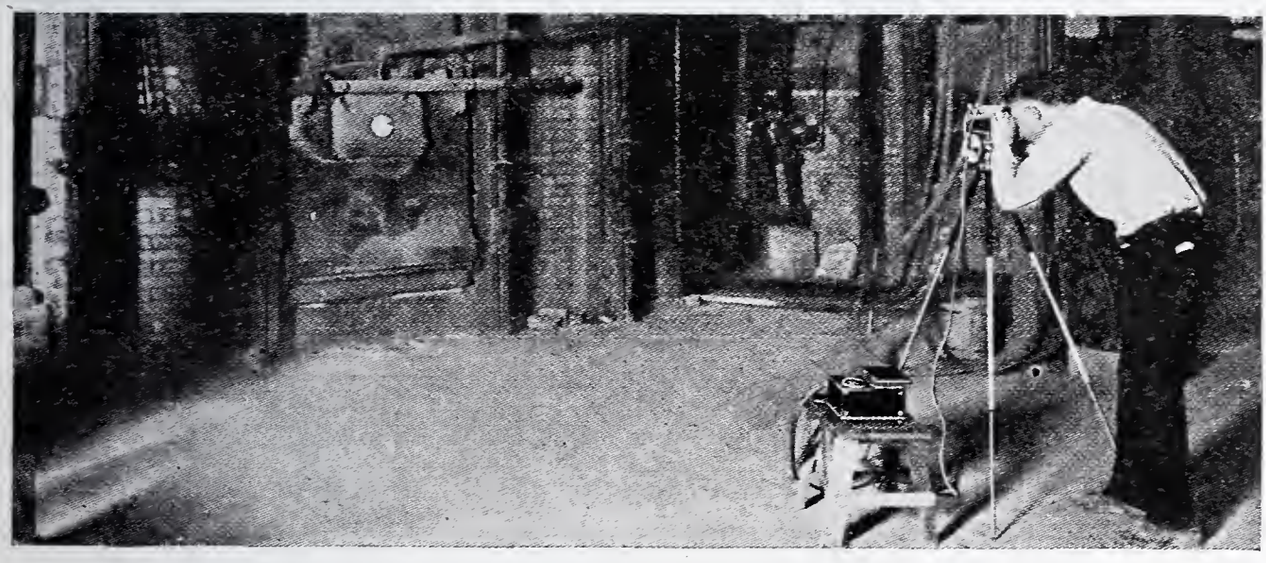


Fig. 6.

Radiation Pyrometer in Use.

HEAT OF THE SUN

The bolometer which is used to measure the heat of the sun is based upon radiation as is also the pyrheliometer, an instrument used for the same purpose, in which the light ray falls on a black disc through a small aperture in a tube, the disc being heated and its temperature subsequently being measured by a thermometer.

In the bolometer, the sunbeam falls on a spectroscope which breaks it up into its component parts. We can only see certain waves in such a spectrum, but others such as the ultraviolet, etc., are also present and it is necessary to absorb the heat of these on lamp black and then measure that heat by the sensitive bolometer. This consists of two very small blackened hair-like ribbons of platinum linked up to two coils of wire to again form a wheatstone bridge which is connected to a battery and a highly sensitive galvanometer, capable

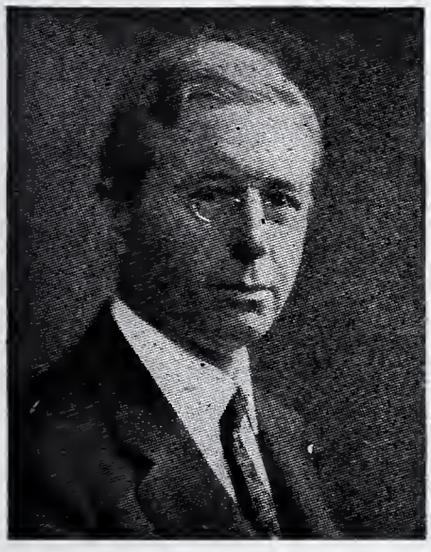
of detecting a change of temperature in one of the platinum ribbons as low as 1/1,000,000 of a degree. As the spectrum is moved over this instrument, its heat effect is recorded on the galvanometer index and a record is kept on a moving photographic plate. Such an outfit, simple as it sounds, requires some twenty pieces of apparatus, weighing several tons and costing in the thousands.

There are many more of these most interesting and fascinating instruments available but time will not permit us to consider them all. We have barely pricked the surface of the subject of heat, its uses, its measurement, its place in our daily lives and very existence, but I believe you will agree with me that it is a most fascinating subject and if you have enjoyed hearing a little about it I shall feel amply repaid for the time I have spent in preparing it for you.

DOPE: THE STORY OF THE USE AND ABUSE OF OPIUM

By Horatio C. Wood, Jr., M. D.

ALL OF YOU are familiar with the beautiful lines of the Canadian poet McCrae, beginning: "In Flanders fields the poppies grow," but perhaps you may not all know that a more famous war poet, the Grecian Homer, sang of the poppy nearly three thousand years ago. But the Asiatic poppy of which Homer spoke was probably not the same species as that which spangled the fields of Belgium with its brilliant scarlet flowers.



Horatio C. Wood, Jr., M. D.

The poppy to which Homer refers* is less showy as a flower but is of far greater importance as the source of the drug known to us as Opium. The Greek word "opion," from which we derive this drug name, signifies a juice and was probably applied to various plant juices used for medicines. But the value of poppy-juice so far exceeded all others that in course of time "the juice" came to mean only one thing, it was not necessary to specify what juice was meant. It is interesting to note that the name of this drug in every language is a corruption of the Greek word "opion." We call it *opium,* the Chinese call it *Ah-pien,* the Turk call it *Ahfyam.*

THE WHITE POPPY

The botanist names the opium poppy "Papaver somniferum" which literally translated means "sleep-bearing poppy." It is an annual herb usually about three or four feet high, with coarsely toothed leaves—not dissected as in the scarlet poppy—and bearing large flowers which vary in color from almost white to purple. Probably a native of Western Asia, it is now extensively cultivated in Persia, Turkey, India and China. It has been grown in other parts of the world, even as far north as England,

*There are two species of poppy growing in Asia Minor, one with scarlet flowers, the other with white; only the latter is medicinally active. While it is uncertain which species Homer meant by *Mekon* the context seems to indicate it was the white flowered poppy.

but its cultivation is not commercially successful in Europe or America because of the high cost of labor.

The seeds are usually planted in November and if the weather be propitious the young plants will survive the winter. In exceptionally cold seasons, however, some of them may be killed and a spring planting required. But the winter poppy is preferred because it yields a larger harvest. In April or May the plants begin to bloom and about June drop their petals. The fruit, which is of the type known to the botanist as a capsule, varies in shape from globular to oval and is about the size of a small hen's egg. As it ripens, it turns a golden yellow color.

It is noteworthy that of the dozen species of poppy there is only one which is known to yield a narcotic juice. Travelers in China sometimes refer to the opium fields ablaze with scarlet, but while there is a red poppy which grows in China it produces no opium. As far as we know no narcotic principle is found in any part of the plant except the fruit. Both the leaves and the seeds have been used for food. The most favorable period for collecting the juice is just as the fruit is beginning to ripen.

COLLECTING THE OPIUM

The method of gathering this crop is today essentially the same as that described by Dioscorides nearly 2000 years ago. When the evening dew has fallen, the collectors pass through the fields armed with a peculiar knife. This knife has a narrow blade, often three of them set parallel attached to one handle. With this implement the operator makes a number of little gashes in the rind of the fruit. Much skill is required in making the cuts because if they are too deep there is likely to be a loss of the valuable juice. Twenty-four hours later the workers pass around the field, bearing a small tray or one of the large leaves from the poppy in their hand, and scrape off the juice which has oozed out through the night on to this receptacle. The soft plastic mass collected is partially dried and afterwards kneaded into balls ranging from one-half to two pounds in weight.

The collection of opium does not appear to seriously injure the fruit which is usually left on the plant and successfully ripens its seeds. After these are thoroughly ripe a second harvest, this time for the seeds, is made. The latter are used either as a foodstuff or as a source of oil.

The opium which comes into our markets is in the form of rounded lumps, usually more or less flattened, of a dark brown color

and with an odor somewhat similar to that of unroasted coffee. It contains a large number of alkaloids, the most important of which is morphine.

OLDER THAN THE SAGE OF COS

Just when mankind first learned of the medicinal virtues of the poppy juice is unknown. The great Hippocrates, usually called the "Father of Medicine" (460-372 B. C.) was familiar with the plant and recommended its leaves as a food, but he does not appear to have been acquainted with its anodyne qualities. Theophrastus, the first botanist and a pupil of the great Aristotle, whose span of life almost overlapped that of Hippocrates (372-285 B. C.), according to Dioscorides, used as a medicine some sort of extract from the poppy which he called "mekonion" (the Greek word for poppy is "Mekon"). Erasistratos, a contemporary of Theophrastus, also refers to the medicinal properties of this poppy, but the earliest positive record of an understanding of its action was from Heraclides of Tarentum (240 B. C.) who used the drug to produce sleep. Pedanius Dioscorides, who was physician to the army of the Emperor Nero, wrote in the first century a magnificent treatise on Materia Medica, which still remains one of the world's great medical classics, in which he accurately describes the method of collecting the drug, and shows a very clear perception of its medicinal virtues.

While from the beginning of the Christian era some knowledge of the effects of opium was widespread among the medical profession, it did not become a popular medicine for many centuries. The famous Galen, whose fiats remained the guiding principles of medical practice for 1500 years, said it was a desperate medicine only to be used in extremities. According to Hill (History of Materia Medica, 1751) the credit of breaking down the prejudice against it is to be attributed to the Swiss physician Felix Platter (1536-1614). It was but shortly after his time that the drug achieved the reputation it still holds of being the most treasured weapon that the physician has at his command in the warfare against suffering.

SYDENHAM'S LAUDANUM

An English physician Thomas Sydenham introduced the alcoholic preparation which we call "tincture" in 1669 and this was for more than a century and a half the favorite form of administering the drug. In 1815 a Hanoverian apothecary named Serturner found that the narcotic proper-

ties of opium resided in an organic alkali to which he gave the name of "morpheum," in honor of the dream god of the Romans, and which we now know as the alkaloid *morphine*. This principle has, to a considerable extent, replaced the older and bulkier forms of the drug. This discovery of Serturner's is of importance not merely because it afforded a more convenient method of exhibiting a valuable remedy, but much more because it marks a turning point in the history of medicine. It was the birth of an idea in pharmaceutical chemistry which dominated that science throughout the remainder of the nineteenth century.

MEDICINAL PROPERTIES

In small doses opium produces, in those not accustomed to its effects, a pleasant feeling of lassitude and well-being. The distresses of life, whether mental or physical, lose their poignancy. With somewhat larger quantities even agonizing pains may be completely abolished. With these larger doses there comes a feeling of drowsiness and if the subject is left alone he will soon fall to sleep. He can be awakened from this sleep, however, by various means, as loud noises or shaking. Even in the severe cases of poison it is nearly always possible to arouse a patient temporarily, but when left alone he will immediately drop off to sleep again.

There is a quite widespread idea that the pleasant drowsiness produced by moderate doses of opium are accompanied with interesting dreams, an erroneous belief apparently founded largely on the writings of that famous English opium eater Thomas De Quincey. The probabilities are that De Quincey's statements about his opium dreams were pure fiction invented during the intervals when he was not under the influence of the drug. Certain it is that if they ever occur they are a very unusual phenomenon.

Life is full of suffering and a large proportion of the physician's activities are directed to the alleviation of pain. Medical scientists have been searching for years for drugs which would abolish pain. With the single exception of the group of remedies of which ether and chloroform are examples, they have never found anything which can compare in certainty or power with the products of the poppy, and the effects of the anaesthetics last but a relatively short time and their value is largely limited to surgical conditions.

OPIUM THE QUEEN

Opium with its various derivatives, such as morphine, stands unrivalled in our Materia Medica as the queen of pain-assuagers. It has other valuable medicinal properties besides this, but had it no other virtue, this one power alone would make it rank as one of the most blessed of drugs.

Imagine a battlefield and a mangled, bleeding, soldier lying out in the cold rain. The over-worked ambulance corps is striving tirelessly to remove the wounded, but one might perhaps lie there for hours enduring most frightful agony until death comes to his relief. The field surgeon, however, comes along, slips out his hypodermic needle with its blessed morphine and in five minutes the torture is gone. Perhaps the wounded man may be gotten back to the hospital an hour or two later, in time to save his life, or perhaps he lies on the field until he dies of exhaustion, but even in the latter case the gift from the opium has, at least, made his dying moments free from agony. Similar conditions may arise in peace time as the result of disease. Even if opium cannot cure the patient, it makes life endurable. Whether he eventually recovers or dies, through its effects he has been spared days and perhaps weeks of torment. Those of you who have never borne or watched the horrible suffering which may come to the sons of men cannot appreciate the ineffable boon which this drug has been to mankind, but the medical profession whose lives are spent in the presence of these horrors, regard it as their greatest treasure.

OPIUM THE CURSE

And now having painted the picture of the gentle, beneficent, Queen Opium, let us look at the portrait of the horrible Circe—alias Dope—robbing men of their humanity and changing them into worse than swine by her fiendish magic.

Human nature is so constructed that mankind is continually taking God's most precious gifts and perverting them to uses by which they become a curse to humanity. Thus, depraved mankind has made of this beneficent assuager of pain the most menacing habit poison of modern times. Of all the drugs in which man indulges for the satisfaction of unnatural craving, none so threatens the welfare of the world as does the juice of the poppy. For a century opium has been called the curse of China, and justly so. People have vaguely believed that it was a Chinese habit occasionally indulged in by Europeans; but it is the curse of America as well as

the curse of China. It is not a Chinese habit in the sense of having originated in that great country. It seems probable that the first use of opium as a habit was among the Moslem people, whose religion forbade the stupefaction by alcohol.

A RECENT HABIT

There is no authentic record of any opium addiction further back than the middle of the seventeenth century, and it does not appear to have been introduced into China until the early part of the eighteenth, although the drug had long been used in that country for medicinal purposes. So rapidly did it gain popularity and so obviously pernicious were the effects of its use, that as early as 1728 an edict against its sale or use was issued by the Emperor.

There is the same sort of morbid interest aroused by the study of this human depravity as is incited by the pathological freaks of the side show, or the instruments of horror in the torture chamber. The victims of the opium habit satisfy their induced cravings by an interesting variety of methods.

THE PIPE

The most romantic and one of the oldest methods, and which is still the favorite among the Asiatics, is opium smoking. Cast your mind back some three hundred years when nobody in Europe or Asia or Africa knew of the solace of tobacco. How extraordinary must have seemed the effects of tobacco to its early devotees. From Sir Walter Raleigh's time the habit spread with furious rapidity all over Europe and into Asia, but soon the smoking of plain tobacco lost its "kick" (to use an untranslatable word from modern slanguage). It was probably a Persian, or perhaps a Turk,* who had the thought of mixing some opium with his tobacco and it is probably in that form that the habit first came to China but her ingenious and artistic sons invented a special technique and a special apparatus for smoking opium; the present-day opium smoker would not think of diluting his narcotic with tobacco. The opium pipe bears little resemblance to the tobacco pipe.

Opium smoking is not widely practiced at present in this country chiefly because of the fact that the elaborate technique requires special places, which constitute what are popularly known as "opium

*Pomet in his "Histoire de Materia Medica" (1694) says that the Turks "when they go into battle take it in excess which puts them out of their good sense," so that they rush headlong into battle without concern for danger.

dens." These are almost impossible to conceal because of the peculiar and pervading odor emitted by burning opium. The activity of our anti-narcotic police, either of the States or Federal Government, keeps this form of vice from ever becoming very prevalent in this country.

Europeans, ever a bibulous people, seemed formerly to prefer taking their dope by mouth. In the last century drinking laudanum was the most common method of indulging their weakness, especially in England. The invention of the hypodermic syringe, about the middle of the last century, opened an opportunity for another, and perhaps the most pernicious, form of the habit. Opium itself is not suited for hypodermic injection but its alkaloid morphine is very potent and eminently available for this purpose.

Probably the most widely employed method among the American habitues is the hypodermic injection of morphine. The method by which the dope fiend injects morphine is essentially the same as that which the physician uses, except that the dope fiend is not careful about the cleanliness of his apparatus and the spots of the injections sooner or later are almost sure to become seats of infection. I have seen the victims of this habit a mass of scars, looking almost like the consequences of a severe case of smallpox, from the hundreds of abscesses which have followed their dirty injections.

About the beginning of the present century chemists busied themselves by modifying slightly the chemical structure of morphine in the hope of finding a new drug which should have the valuable medicinal properties of morphine without some of its objectionable features. Among the products of these activities was an artificial alkaloid which was introduced into medicine under the name of heroine—But it has turned out to be the villain of the dope tragedy! Of all forms of addiction it is probably the most baleful. So destructive and seductive is it, that despite its valuable medicinal qualities the importation or manufacture of heroine in the United States is forbidden by special Federal enactment. Nevertheless it is the most popular of the opium products among the underworld of the Atlantic States. As all of it has to be smuggled into the country, comparatively little of the drug finds its way to the centers of the country far removed from ports of entry.

A curious feature of heroine addiction is that its devotees usually take it by "sniffing;" that is in much the same way that the dandy of a century ago took his tobacco in the form of snuff. There appears to be some strange pleasure in the tickling the inside of the nose.

EFFECTS OF HABIT

Ambition is the child of discontent. Man strives for something new because he is not satisfied with what he has. Feeling the discomforts of poverty he toils with vigor for money; desiring to be the giver, instead of the receiver, of orders he strives for power; pained by the suffering of humanity he devotes his life to the search for better methods of curing disease. Destroy dissatisfaction and you kill progress.

The primary effect of dope is precisely that destruction. It soothes pain and assuages grief. Under its influence the devotee is no longer unhappy in his poverty nor concerned for the misery of others. Why should he strive or struggle? All he asks is to be allowed to enjoy in quietness the pleasant languor of indifference. But after a time the effects of the drug begin to wear off and he gradually awakens to the unpleasant realities of life; to his previous causes for dejection is added the prick of conscience at the cowardly mode of escape he has employed. Tormented by his troubles, lacking the courage to take up arms against them, he flies again to the former nepenthe. So the round begins again. Each time that he awakens from its pernicious serenity the stronger is the yearning to return. From repeated use the drug begins to lose its power. No longer is the tranquillity a pleasure, only the awakening is a torture; oblivion becomes his highest hope. But merely to quiet the devils of consciousness requires ever increasing doses and eventually there is added to the moral deterioration the physical injuries of poisonous doses.

And now enters on the scene a new problem. The increasing doses become a financial drain, the blighting effects, both mental and physical, are diminishing his earning power. He *must* have the drug. How to get it is his only anxiety. No sense of morality, no fear of punishment can restrain him. Usually he lacks the virility for crimes of violence, but no act is too repulsive or mean for the confirmed dope addict. Well is he called a dope "fiend." He will lie, he will steal, he will sell his daughter, he will cheat his best friend. He becomes the most despicable of the criminals who fill our jails. Bootleggers and sneak thieves are recruited from the slaves of opium.

I do not hold, as do some authorities, that these symptoms show that opium causes a breakdown of the moral character. If you were starving and a rich hard-hearted neighbor refused to alleviate your need, to help yourself to some of his excess would not necessarily betoken an unusual moral weakness. The pangs of hunger are trivial to the torment of opium deprivation in the addict. His conduct

arises not so much from a failure to appreciate the wrong of his action as from the violence of his yearning which dominates all other considerations. My experience of drug addicts is that when their craving for dope is stilled their moral character is not very different from the mass of mankind.

One who has never witnessed the suffering induced by opium hunger in the addict can form no idea of the frenzy of torture; at times it even surpasses the limits of human vitality and the sufferer may die of exhaustion.

Of all the drug habits which have enslaved humanity—tobacco, alcohol, hasheesh—none forges stronger chains nor exerts a more baneful influence over its victims than opium. Rich and poor, genius and dolt, young and old have been its prey. I have already referred to that erratic genius Thomas De Quincey who, despite his native talent which occasionally burst into dazzling eloquence, has left behind him only one enduring piece of literature his "Confessions of an English Opium Eater." This barrenness I think may justly be attributed to the opium habit he acquired while yet a student at the University of Oxford. Samuel Taylor Coleridge, the author of that beautiful, if somewhat gruesome poem, "The Rime of the Ancient Mariner," whose work as a critic and philosopher as well as a poet places him in the very forefront of English men of letters, became addicted to the drug in early middle life. A biographer in writing of this period of his life has said: "Little by little the habit grew and the black drop at length enslaved him. It injured his constitution, killed his imagination, enfeebled his will and destroyed his sense of truth and honor." In the latter years of his life Coleridge wrote: "After my death I earnestly entreat that a full and unqualified narrative of my wretchedness and of its guilty cause may be made public, that at least some little good may be effected by my direful example."

We may be tempted to minimize the destructiveness of opium addiction when we read of men whose native endowment was great enough to save something worth while from the wreck of their lives, but we do not hear of the thousands of men of brilliant promise whose lives were ruined by their slavery and whose deaths were unrecorded and leave no mark in history. The public knows only of those exceptional geniuses whose flame could shine even through the murk of their opium-clouded intellects; it hears but little of the ruined morals that fill our jails with opium criminals and of the blasted lives that become economic parasites on society.

I suppose that many of you, if not most of you, have known of a drunkard who, after almost completely wrecking his life on the rock of alcoholism, broke his slavery and became a useful citizen. I have known many dope addicts, but I never knew one of them to permanently give up the opium habit. I once heard the late George Long who served fallen humanity for so many years as the head of the Inasmuch Mission, a reformed drunkard and jailbird, say in a public speech that he had been also at one time an opium habitué. I should not, therefore, like to be understood as saying that no one was ever cured of the habit, but I have not met personally anyone who was.

If this story that I have been telling you tonight is true, and dope is in reality the menace to national prosperity that I have painted it, why have not the governments of the world done something about it, you may ask. To which I reply that they have.

CHINA FIRST AGAIN

Apparently the first people to realize how serious is the peril hidden in the insidious poppy juice was the Chinese. In 1728 the Celestial Emperor issued the first edict against this habit. It was not until 150 years later that the Caucasian nations began to realize the possible disaster foreseen by the Mongolians. Europeans, with that inexplicable smugness of supposed racial superiority with which the white race is wont to regard the yellow, dismissed the subject of opium habit with the thought that it was a peculiar weakness of the Chinese and that the more virile Caucasian would never become entangled in its meshes. Our complacency blinded us to what was going on.

In 1906 Bishop Brent, whose activities as Episcopal Bishop in the Philippine Islands had brought him to realize the destruction wrought among his Chinese parishioners, together with Dr. Hamilton Wright, appealed to President Roosevelt to take some action in the matter. They succeeded in arousing his interest and when Roosevelt was aroused something generally happened. An investigation of the conditions in this country caused a wave of horror, if not terror, whose movement was felt even in Europe, and in 1909 was held the first world conference on the control of the opium habit at The Hague. A second Hague conference held in 1912 led to the passage of the Harrison Narcotic Act by the United States Congress in 1914. Today publicists and physicians all over this country and in Europe are alive to the menace of the situation.

THE LAW STEPS IN

Since the passage of the Harrison Narcotic Act and the subsequent enactment by many state legislatures of similar laws, the Government has waged a vigorous, if not entirely successful, campaign against the great kingdom of dope. With a law so stringent as the Harrison Act and with an organization so powerful as the United States Government, the ordinary man of the street cannot see why more is not accomplished, but he underestimates the powers of the Principalities of darkness. He is prone to cry "Graft" and to accuse the Government agents of slackness if not actual dishonesty.

I have known several of the Federal narcotic agents and all that I have met were intelligent, energetic officials with a real interest in their work. I believe that the great majority of them are as honest as the majority of this audience; that their failure to enforce the law is due to the magnitude of the task that confronts them. You have, through reading the newspapers, some hazy concept of the difficulties of prohibition enforcement. If you remember that an ounce of morphine (that one can easily carry in one's pocket) is worth $20, you get some idea of how vastly more difficult it is to prevent the smuggling of morphine than to stop the smuggling of whiskey; and if you will realize that there is absolutely no price that the dope fiend will refuse to pay, you begin to understand how great are the temptations for the unscrupulous to engage in this traffic. When whiskey goes to $10 a quart most of its devotees stop drinking, but when morphine goes to a correspondingly exorbitant price, its devotees turn highwaymen or burglars to get the money to pay the price.

As long as opium is available it seems almost hopeless to stop this smuggling. Most of the students of the problem have become convinced that the only hope of ultimate success lies in destroying the stream at its source; that is, we must come to the regulation of the production of the crude drug and that can be successful only by international agreement. If, for example, China, as she once did, stopped the cultivation of opium it would result only in the larger production in India or Persia. To be successful such a move must be joined in by all the world unitedly. So strongly did the authorities at Washington feel the truth of this, that although Congress has not allowed this country to become a member of the League of Nations, they did send an American delegation to the conference called by the Opium Committee of the League in 1924. Incidentally that Conference was shipwrecked on the same rock of national selfish-

ness that has smashed so often the hopes of world disarmament. We are today in precisely the same situation toward the solution of this problem that we were ten years ago, with the single exception that there is a wider appreciation of its importance.

I would not have you think me a pessimist. I confess that I see little prospect of any international agreement on the opium question in the near future, but I do not feel that we should therefore abandon the struggle as hopeless. I am convinced that much has been accomplished in this country, that there is a decided decrease in the number of drug addicts in the last sixteen years. I have faith enough in the American people to believe that if the world will not help us we are still strong enough of ourselves to break the chains of drug slavery, be it opium or alcohol.

KING COTTON

By George Wesley Perkins, M. Sc.

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"KING COTTON" is a king indeed, a product which in its various manufactured forms gives employment to more human beings than any other product in industry. To plant and produce the cotton crop of this country alone, more than 2,500,000 farmers and laborers are required; for the cotton crops of other countries, more than 1,500,000 workers are needed. In 1925, in the United States, 468,352 persons in 1,638 establishments were employed in the spinning of the cotton fiber and weaving of cotton cloth. In Great Britain, in 1921, 588,000 persons were employed in a similar capacity. In 1914, the acreage devoted to cotton growing in the United States, was 37,406,000, which has not been equaled since. One can readily see that a very large part of our population are directly and indirectly dependent upon the continued prosperity and stability of the cotton industry.

George Wesley Perkins, M. Sc.

KING COTTON

About ten years prior to the Civil War, David Christy published a book called "Cotton is King or Slavery in the Light of Political Economy." Shortly, after in 1852, James H. Hammond used the phrase "King Cotton" in the United States Senate. As far as we know the usage of this phrase dates from this time.

Cotton was known in India before the conquest by Alexander, and Herodotus (445 B. C.) refers to this Indian cotton in some of his writings. Marco Polo, in some of his writings says that India produces "the finest and most beautiful cottons that are to be found in any part of the world" (about 1298 A. D.).

The Greeks, Romans, Moors and Mohammedans are accredited with having spread the use and manufacture of cotton cloth to other

parts of the civilized world. In Egypt, however, flax was the common material from which clothing (linen) was made, and all mummy cloths so far examined have been found to be linen cloth; this does not signify, however, that the use of cotton was unknown to the Egyptians, for there is some confusion in the early writers respecting the terms used for "flax" and "cotton." In China and Japan silk was the customary dress and the introduction and use of cotton cloth was very slow. The cotton cloth in use in India at this early date, although woven in a crude and primitive manner was of good quality and degree of fineness.

BY ANY OTHER NAME

Some of the names given to the cotton fiber in different countries are as follows:

India	Pucu
Spain	Algodon
Yucatan and Ancient Mexico	Ychcaxihitvitl
Tahiti	Vavai
France	Coton
Italy	Cotone
Germany	Baumwolle
Persia	Pembeh or Poombeh
Arabia	Gatn, Kotan, or Kutn
Cochin China	Cay Haung
China	Hoa mein
Japan	Watta ik, or Watta noki
Siam	Tonfaa
Hindoostan	Nurma
Mysore and Bombay	Deo Kurpas and Deo Kapas
Mongolia	Kohung

The cotton plant is indigenous to Peru, and cotton cloth has been used in Peru from an early date. Ancient Peruvian mummies have been found wrapped in cotton cloth. The North American Indian was acquainted with some varieties of cotton, only those tribes, however, in the southern part of the country. The Indians used the fibers of a great many different plants to make strings, nets and in some cases clothing.

Cotton cloth was one of the first American products mentioned by the narrators of the Columbus expeditions. One of the earliest written documents relating to Columbus states that on the Island of

Guadalupe, during the second expedition was found "a great quantity of cotton, both spun and already prepared for spinning." Ferdinand Colon, the son of Columbus, relates in one account that on the first voyage, a considerable quantity of cotton was seen in one house and further that "the cotton grows naturally about the fields, like roses, and open of themselves when they are ripe, but not all at the same time; for upon one and the same plant they have seen a little, young bud, another open, and a third coming ripe, . . . none of them (the Indians) make use of it to clothe themselves, but only to make nets for their beds which they call hamacas."

Another early writer, Rochefort describes a second kind of cotton which crept along the ground like a vine. These two kinds of cotton are still common in the West Indies. There is slight evidence that the Indians ever extensively cultivated the cotton crop. In 1540, the Spanish Explorers in the Southwest, found cotton in use among the Indians of Arizona and New Mexico, and it seems quite probable that it was a cultivated crop, for we know that they had a high degree of civilization.

The actual origin of the different varieties of cotton in use today, is doubtful. There were some native American varieties and some Old World sorts; and both are perennials if planted south of the "Frost" line. There is a strong possibility that some of the present strains are the results of crossing Asiatic and native American plants. In the eighteenth century, cotton growing was beginning to be an important industry in the South, but very little was exported. The English manufacturers favored the Asiatic (East Indies) cotton because it was white and wove white. Some of the early southern planters obtained the seed of the Asiatic variety and tried them with success. In 1746, some of this introduced cotton was sent from Virginia to Manchester, and there it sold for eighteen pence a pound. Not, however, until after the Revolution, did the export trade in cotton begin.

In 1669, the Lord Proprietors of the Colonies, of the Carolinas, sent an expedition, under the leadership of Joseph West, to settle on Ashley River. West was instructed to stop at the Barbadoes and procure a supply of: "Cotton Seed, Indigo Seed, Ginger wots;—some Canes (sugar canes) Olive setts,—half a dozen young sows, and a Boare." Under West's leadership, the first agricultural experimental farm was established for the purpose of testing the adaptability of these crops to the soil of Carolina. After two seasons' trial,

the Lord Proprietors were informed that sugar cane and cotton would not stand the winters in Carolina. The trouble was due to the fact that the annual and not the perennial varieties were used. Then it was found that the perennial variety was satisfactory, and an advertisement of the Carolina Company, published in 1682, in England, stated "Cotton of the Cyprus and Smyrna sort will grow well, and good; plenty of the Seed is sent thither."

An interesting activity of the Connecticut colony in the year 1640, was the laying of an assessment "to provide a vessel to trade for cotton wool," not that they wanted cotton clothing especially, but they had discovered that a coat well padded with cotton was an efficient protection against Indian arrows and later every family was ordered to have one such coat in its possession.

The French in Louisiana, introduced and grew and improved a strain of cotton that was a species of the white Siam, and was much better and brighter than the cotton of the English colonies.

FAMILY HISTORY

The cotton plant is closely related to a flower that is probably known to most of us, namely, the Althea or Mallow, both members of the natural order, Malvaceæ. The genus, Gossypium, of this order, contains the different species of cotton plants.

The plant is a shrub from two to six feet in height, and requires a fairly rich soil and a warm climate. The season for sowing the seed is from the middle of March to the middle of April, in this country. The plant will flower in June and the bolls will ripen and burst open in September.

There are two principal types of cotton, the long stapled and the short stapled. The former is called Sea Island and Egyptian Cotton and the latter is called Upland Cotton. Most of the cotton is of the latter variety.

The cotton is picked by hand at a cost of about fifty cents per 100 pounds. A day's picking will be about 300 pounds, and a good picker averages around $1.50 per day. An acre of ground will, on an average, give close to 200 pounds of cotton.

The cotton is collected and gathered and weighed and then carried to the gin. The cotton gin was invented by a Yankee school teacher, who found himself out of work in the South, namely Eli Whitney. Whitney, was a Yale graduate who had earned his way

through college by his mechanical skill and was very ingenious in the application of machinery.

One day, Whitney, on a visit to the plantation of Mrs. Nathaniel Green, met some Southern cotton growers who told him of their need for a device to separate the seed from the cotton. In a few weeks he developed such a machine. This completely revolutionized the output of cotton. At the time of Whitney's death, in 1825, fifty times as much cotton was being produced.

The cotton gin is essentially a lot of circular saws, mounted on the same shaft and the saw blades pass through narrow slits or fingers. The seed will not pass through the slots and the cotton fiber is literally cut and pulled from the seed. A rotating brush sweeps the cotton from the saw. Upland cotton when ginned produces seed with a certain amount of linters attached. In order to get the linters off, specially constructed gins with closer and finer saw teeth are used.

The Sea Island cotton fiber separates readily from the seed. The raw cotton from the gin is compressed into bales in a hydraulic press to an average weight of 500 pounds. The raw cotton after ginning and baling is loaded in flat cars, boats, etc., and shipped to the big cotton warehouses to be sampled and graded. There are thirteen grades or designations for the quality, staple and condition of the cotton that are officially used. Grade and value do not run parallel except for cottons that have the same qualities of staple. Impurities in cotton are generally, leaves, dirt, cut seeds and strings and unripe fibers.

MAKING THE GRADE

In the commercial grading of cotton, a classification is adopted with reference to the quality of the fiber. The usual grades are as follows:

Fair
Strict middling fair
Middling fair
Strict good middling
Strict good ordinary
Good ordinary
Strict good middling tinged
Good middling tinged
Good middling
Strict middling
Middling
Strict low middling
Middling tinged
Strict low middling tinged
Low middling tinged
Middling stained.

The "fair," "middling fair," "middling," etc., are known as full grades, while those intermediate are half grades. The "middling"

grade is the one universally employed as a basis for all cotton trading and the price of cotton is fixed on this standard.

The principal factors in the grading of cotton are length of staple, uniformity strength, color, cleanliness, and flexibility. The first may be determined by the gradual reduction of a tuft of cotton by the hand until individual fibers are drawn from the tuft, so that their length may be ascertained. The uniformity of staple is also important, for if the staple is uneven the cotton is of less value than if it were somewhat shorter but more even. The color of the fiber must also be considered, because this is of importance in maintaining an even shade of yarn. The cleanliness of the fiber affects the amount of waste made in the mill and hence is an item of great importance. The flexibility of the cotton is best ascertained by the feel; flexibility does not necessarily imply lack of strength, but rather includes it, for a weak fiber is more liable to be brittle than flexible. On the other hand, a fiber may also be strong and harsh and yet not flexible, and hence less suitable for fine spinning. The strongest cottons are used for warp yarns as such yarn is required to withstand considerable strain during weaving, a feature which is not required to such an extent by filling yarns. The latter, however, require a soft and flexible fiber.

The cotton fiber has a very characteristic appearance. It looks more or less frayed and twisted and is readily distinguished under the microscope from any other fiber, due to this peculiar twisting shape. It consists of an outer cover called the "Cuticle"; the inner part is pure cellulose and contains a canal in the middle which represents the nucleus of the cell.

The natural, spiral-like twist present in the cotton fiber causes the latter to be especially adaptable to purposes of spinning. The spinning qualities of the cotton fiber, however, depend not only on the nature and amount of twist which causes the individual fibers to lock themselves firmly together, but also on the length and fineness of staple.

After the cotton is ginned it is sent to the mill to be made into yarn. After the bale is opened it is run through more machines, where it is beaten up and torn apart and then put through a carding machine, which contains thousands of tiny wires which comb the cotton and lay it in parallel rows. After the cotton is carded it is run through another machine, where it is then combed and divided into

small strands. The fibers, being in parallel rows, go from one machine to another until the fibers are reduced in size by constant drawing and twisting until it gets harder and stronger and further reduced in size, and finally we have the cotton thread.

By numbers or counts in cotton the following is meant: No. 1 would mean that the thread would contain 840 yards to the pound, a thread such as used by the housewife on a sewing machine like No. 60 would be 60 times 840 yards in length in 1 pound of weight of the thread.

It seems that we can grow nothing of economic and important use to man unless there is some pest that interferes with the growth of various plants. In the South we have the young cotton boll infested by the "boll-weevil," a member of the beetle family. It seems that in 1892 this little beetle or weevil, about as large as the common house fly, crossed the Mexican border and began its invasion of the southern cotton States.

The boll weevil spread from year to year until by 1921 the whole of the Cotton Belt in the South was infested by the insect. In the same way we note the spread of the Japanese beetle, as each year it is necessary to increase the area under quarantine. An enormous amount of research has been done by the Department of Agriculture at Washington to determine the best methods for combating the weevil, but the little pest seems to be holding his own. It is interesting to note that in one part of the South the weevil was a blessing in disguise. In the town of Enterprise, Coffee County, Alabama, there is a very large and beautiful monument erected to the boll weevil, for this reason: before the weevil had invaded as far as that county in 1915 the average cotton crop was 35,000 bales, but in three years the crop was reduced to 3000 bales. Their sole means of livelihood was cotton and absolute ruin was imminent. Diversification of crops was tried and peanuts, corn, hay and sweet potatoes were planted, the income from these crops was more than that received from the former cotton crop and the farmers were saved from extermination through this diversification of crops and not by depending solely upon cotton. Intensive methods must be used to combat the weevil and in order to protect the large acreage of cotton, airplanes are being used to dust the insecticidal powders such as calcium arsenate, saving considerable time and labor. In the same way some of the large fruit growers in California dust their large orchards, in

other words they cover the orchards or fields with a "smoke screen" composed of the necessary insecticide.

Great Britain leads the world in the production of cotton cloth and yarns. There are several reasons for this: first, our country was still a large farm (Colonial period) when England had large manufacturing centers; second, in order to successfully spin cotton yarn the atmosphere must be more or less humid, especially in spinning fine counts (fine threads). The climate of certain parts of England is exactly suited for this purpose. Great Britain owns about 40 per cent. of the world's spindles and manufactures about half of world's production of cotton cloth.

In 1844, John Mercer found that when cotton was passed into a 30 per cent. solution of caustic potash it shrinks and gains 50 per cent. in strength, and at the same time assumed a high degree of luster. This process is known as mercerizing. Essentially, it relates to the action of certain chemicals on cellulose, whereby the latter is changed to a product known as cellulose hydrate, although, technically, the term has come to mean the process concerned with the imparting of a silk-like luster to the fiber. As generally understood, it consists briefly in impregnating cotton with a rather concentrated cold solution of caustic soda and subsequently washing out the caustic liquor with water, the material being either held in a state of tension during the time it is treated with the alkali in order to prevent contraction, or stretched back to its original length after treatment with the alkali, but previous to washing, in either case, the material must be in a state of tension during the process of washing.

MERCERIZING

Cotton is largely mercerized both in the form of yarn and woven fabric. Yarn mercerizing may be carried out in the skein or in the warp; the latter being the favorite process in use in America, while in Europe nearly all yarn mercerizing is done in the skein. Machines for skein mercerizing are so arranged that the hanks of yarn are stretched between revolving rollers and successively subjected to the action of caustic soda, a washing with warm water, and finally a washing with cold water. The operation of most forms of machines is entirely automatic. In another form of apparatus the hanks are placed over a perforated horizontal drum, the latter is then revolved at a high rate of speed while the solution of caustic soda is applied from the inside and washing with water is done in the same

manner. The tension in this machine is produced by the centrifugal force arising from the high speed of rotation.

A silky luster resembling that produced by mercerization can be given to cotton cloth by means of what is known as a calender finish. This is accomplished by passing the cloth between rollers under heavy pressure, one of the rollers being engraved with obliquely set lines ruled from 125 to 600 to the inch. The effect is to produce a great number of parallel, flat surfaces on the cloth, which causes it to acquire a high luster. By conducting the operation with hot rollers quite a permanent finish can be produced which closely approximates mercerized cotton. Cloth so finished, however, loses its luster in a large degree on washing.

The cottonseed as they come from the gin still have short fibers attached to them. These fibers are known as lint or linters. The seed are passed through a machine similar to the regular cotton gin, but made with finer teeth and practically all of the linters are removed. About 10 per cent. of the weight of seed consist of these linters before removal. These linters are used in the manufacture of cotton batting and of nitrocellulose.

Nitrocellulose is also known as guncotton, soluble cotton, pyroxylin and chemically as cellulose nitrate. In 1855 a Swiss, Andemars, patented a process for spinning a thread from an ether-alcohol solution of nitrocellulose. Several years previous several workers had found that the nitrocellulose was soluble in a mixture of three parts of ether and one of alcohol but not in ether or alcohol alone. This solution of the nitrocellulose in ether-alcohol was known as collodion and was used in the "wet-process" photography. An amateur picture taker of that day had to carry an enormous amount of material with him in order to take pictures by this process, for it was necessary to prepare his plate, expose it, and then develop it right on the scene. Today one purchases a film made perhaps months before and it can be developed within a reasonable time after the exposure has been made.

The successful realization of the idea of spinning a solution of cellulose into a fiber was accomplished in 1884 by a Frenchman by name of Comte de Chardonnet. This process is one of those used today by several large companies, hence the name Chardonnet silk. Nitrocellulose alone is very inflammable and clothing made from it would upon ignition cremate the wearer. The degree of inflammability depends upon the extent of the "nitration" of the cellulose. Arti-

ficial silk made by this process is "denitrated" after spinning by passing the thread through certain chemical solutions (ammonium sulphide).

Later some different workers found that cellulose would dissolve directly in a solution of copper oxide in ammonia water, and this solution of cellulose when spun into an acid bath would process a thread of cellulose with a silk-like luster. So today we also have the cuprammonium process for making rayon by this process.

In 1892 two English chemists, Cross and Bevan, began an extensive research on the composition of cellulose and discovered that it was capable of forming a compound called cellulose xanthate, made by treating cellulose with caustic soda and carbon disulphide. This solution was called viscose because of its viscosity, and when spun into an acid bath produced a thread of cellulose that was silk-like in character. Today 80 per cent. of the artificial silk or rayon made in this country is by this process and it is known as viscose silk. An immense plant for the manufacture of viscose silk is situated down at Marcus Hook and has been in operation for a number of years. About 85 per cent. of the stock of the Viscose Company of America is owned by Courtaulds, Limited, of England, and since 1914 has made a net profit each year of from 12 to 30 per cent. of the capitalization, a very profitable business indeed.

Another cellulose product discovered by Cross and Bevan is known as cellulose acetate and this product has just recently been used on a commercial scale. Celanese silk is made from cellulose acetate. When cellulose acetate is made into motion picture film it is called non-inflammable or slow-burning film because it burns slowly compared with the nitrocellulose film stock.

These four processes as briefly mentioned above are the means by which all of the cellulose products of a rayon type are prepared, that is to say, some form of cellulose from a natural source, like cotton linters (there are numerous other sources of cellulose, but we are discussing in this lecture only such products as have their principal origin in the cotton plant) is totally changed in form by solution and from that prepared solution of cellulose compound the cellulose is regenerated and spun into a thread or filament, or made into sheets, or made into tubes.

The regenerated cellulose in the form of threads is called rayon or by the older name artificial silk; in the form of filaments or thick threads it is known as artificial horsehair; in the form of films it is

known as cellophane, and this also includes photographic film which is called "film"; it may also be in the form of tubes of various sizes, known as straws for the smaller sizes up to tubing used for the casings around "hot dogs" and cigar wrappers, etc. There are other cellulose products rightly so called such as paper, etc., but they are not made from the cellulose of cotton.

After the formation of the rayon thread it is made up into skeins or wound on bobbins. Various kinds of fabrics can then be woven in the usual way. It is interesting to note that although there is considerable waste in the manufacture of rayon all of the waste saved by special processes is spun into yarn. The yarn spun from this waste is, strange to say, stronger than a straight rayon spun yarn.

An ordinary pair of men's silk socks will weigh about 14/12 of an ounce (1 dozen pairs = 14 ounces). The size of the yarn in the socks averages about 33 times 840 yards to the pound, so one pair of socks unraveled would stretch about two miles. For all rayons except acetate rayon (cellulose acetate) the ordinary cotton dyes can be used. In a square inch of dyed sock there are about 20,000,000,000,000,-000,000 molecules of dye, but if each molecule were the size of an orange the whole area of the United States could be covered about 3000 feet deep.

Viscose silk is also made from wood pulp, but all nitrocellulose is made from cotton linters. The Hercules Powder Company, of Wilmington, Del., is the largest single producer of nitrocellulose in the world. The cotton linters are treated with a mixture of nitric and sulphuric acids and then whirled in machines to get rid of the excess acid just like clothes are dried in the laundry. The nitrated cotton linters which are now nitrocellulose is boiled for days in very large wooden vats to get rid of the last traces of acid, for traces of acid might cause decomposition of the product if it is stored for a period of time.

The estimated world production of rayon, or artificial silk, is 397,125,000 pounds, of which the United States produced 131,325,000 pounds in 1930. The world's total production of artificial fibers today amounts to only about 3 per cent. of the natural fibers.

From this nitrocellulose we can make rayon, as noted above, or pyralin (celluloid), artificial leather or lacquers. Some years ago a man by name of John Wesley Hyatt, of Albany, N. Y., a typesetter by trade, heard of a prize of $10,000 that was offered for a substitute to replace ivory tusks in the manufacture of billiard balls. He had

heard that two men, Parks and Spiel, of England, had prepared a plastic mass with camphor and nitrocellulose dissolved in a solvent and with castor oil; they labored under the impression that castor oil was necessary to make the product plastic. What is known as flexible collodion today contains some castor oil, but the product is nothing like celluloid. Hyatt was a great believer in heat and pressure because of his experience with printing presses. Hence, in 1869, he found that when he took a mixture of nitrocellulose and camphor, mixed them together and then put them in a hot press, that a plastic mass was obtained which could be molded into all kinds of articles, and so we have the beginning of the celluloid industry.

Cellulose that is only moderately nitrated is generally called pyroxylin; if medium nitrated it is called nitrocellulose, and highly nitrated cotton (cellulose) is called guncotton. The further the nitration is carried on the cellulose the more inflammable it becomes. Cotton we know will only burn very slowly or smoulder, while pyroxylin burns quickly and guncotton burns in a flash, so that a piece of guncotton can be held on the palm of the hand and ignited and it will burn so quickly that one will not be burned. This property makes it valuable as an explosive. If the product was used alone in a big gun it would burn so fast that the gun would explode before the shell could be propelled out of the muzzle. By dissolving the guncotton in a solvent like acetone and then molding it into the form of rods, cubes, or grains, the speed of burning can be slowed down to almost any desired rate, and since it does not leave any soot, it is called smokeless powder, and millions of pounds of it are used every year. If guncotton is mixed with nitroglycerine and a little vaseline we have an explosive known as "cordite," and it was invented by a Swedish chemist, Alfred Nobel, the founder of the Nobel prize. Nobel is also credited with the invention of dynamite.

The development of the production of wide sheets of various thicknesses of cellulose is comparatively new. These products are generally collectively known as cellophane and can be produced in very thin sheets and dyed at the same time in various colors. This product is used extensively today for wrapping all kinds of products. They are made mostly from "viscose" cellulose. Thick sheets of the celluloid type and of the cellophane also can be embossed with various finishes (like moire) or incorporated with different pigments or with an extract from fish scales (pearl finish pyralin products). Thin solutions of cellulose when mixed with the material of fish scales and coated on the inside of thin walled spheres are called artificial pearls.

When solutions of nitrocellulose in different solvents are mixed with pigments and certain gums or resins and the resultant product coated on wood or metal, a very beautiful finish can be produced. These solutions can be sprayed, brushed or dipped on the article to be coated and collectively are known as lacquers. Everyone is familiar with the extensive use made of them today. Great economies have been made in some industries through the use of these types of covering materials (notably the automobile industry).

When solutions similar to lacquers are coated on canvas or other fabrics a textile product can be produced that is used in place of leather (artificial leather); in fact, the technique of this manufacture has advanced to the stage that is very hard sometimes to distinguish between real and artificial leather.

Cotton seed at one time was an item of waste and it was an economic item and was allowed to rot until someone discovered that it made a good fertilizer. Finally, someone found that an oil could be obtained by expression of the seed. After the linters are removed, the seeds are crushed and cooked, placed into machines and made into cakes which resemble large waffles and then placed in hydraulic presses where the oil is expressed from the crushed seed.

We have a large number of products which are obtained from the cottonseed oil. One of the more familiar products is "Crisco." It is made in a large cylindrical vessel containing a shaft to which is fastened a screen which continually revolves and into this vessel, the oil is pumped and hydrogen is introduced therein under pressure. After this batter turns for a time a certain amount of hydrogen is taken up and the oil is converted into a solid which is very clear and bland and has a wide range of uses.

Some of the cottonseed oil is used as salad oils, etc., and some of the hydrogenated oils are made into food products, and one of these substances is "oleomargarine." This is a very carefully regulated industry, because the slightest contamination in the product would result in no sale. It is made from milk, hydrogenated cottonseed oil and other fats. The milk is pasteurized and inoculated with certain kinds of bacteria and then quickly chilled and put into large vats and churned with the oils and fats.

After this is churned for a certain time it is churned into a vat of cold water and carried towards one end of the machine on a traveling belt. This takes out certain substances made in the churning process. It is then put on circular tables, similar to those used in the manufac-

turing of butter, and then taken to another room, where it is placed in a hopper and then cut in another machine into the familiar one-pound bricks and then wrapped and sent to the packing room.

An important by-product of the cottonseed is cottonseed meal, obtained after expressing the oil from the cottonseed oil-cake. The meal has been used for some years as a fertilizer and also as feed for cattle. Because of its protein content it has also been proposed to use the meal-cake as a synthetic beefsteak. The protein content of the cottonseed meal is 12.80 gm. per 100 calories compared with 9.05 gm. of protein per 100 calories for whole eggs. As a meat substitute it could be retailed for five cents per pound, with a yearly supply of millions of pounds.

From the hulls of the seed also known as cottonseed "bran" a sweet sugar by the name of xylose can be obtained by suitable chemical manipulation and extraction. This sugar contains five carbon atoms in one molecule, whereas ordinary cane sugar contains twelve carbon atoms in one molecule. This sugar can be produced and sold for five cents per pound, with a yearly production of one to one and a half million pounds.

Apropos of the miniature golf craze, thousands of the putting greens of these courses are covered with a matted or felted mixture of dyed cottonseed hulls.

The kingdom of KING COTTON is indeed a vast dominion.

THE RAT MENACE

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MAMMALS form one of the great classes of vertebrate animals. The greater number of mammals belong to one group known as Eutheria or the modern mammals, which in turn is subdivided into various "orders." One of the most extensive orders of this group is the Rodentia or Glires. The latter, the rodents or gnawing animals, are characterized by the peculiar arrangement of the teeth. The canines are always absent, but in the front of the mouth are the incisors. The latter are large conspicuous and chisel-like and with but few exceptions there are never more than a single pair in each jaw, which meet vertically like two pairs of chisels, forming a very powerful apparatus for gnawing or cutting. The incisors are curved and deeply rooted in the jaws, and grow throughout the entire life of the rodent from the base as they wear away at the tip. The remaining teeth, the molars, are broad flat-topped grinders, few in number, rooted or rootless, and situated in the back of the mouth. Between the molars and the incisors a wide bare space exists.

Louis Gershenfeld, Ph. M., B. Sc., P. D.

The rodents range in size from the mouse to the beaver and they present much diversity of habit. Most of them are terrestrial, as the rabbits, etc. Many are burrowers, as the gophers, mole rats and marmots. Some are arboreal, as the squirrels; others as the muskrat, beaver, etc., are aquatic. They run, leap or jump, climb and like the flying squirrel even sail through the air. Like the rats and mice, they may be gregarious, or solitary as the woodchuck or display other characteristics. No matter what marked characteristics or special peculiarities they may possess individually, mammals are grouped in this order (Rodentia) primarily because the characteristic incisors or gnawing teeth are present, the one peculiar trait or feature which "earmarks" all members of this order.

Rodents are cosmopolitan, found over the entire globe. The greatest numbers are found in South America, while but few members

of this order are to be found in Australia and Madagascar, and on certain oceanic islands they are but rarely observed. In North America there are more than 400 species represented by the Rabbits and Hares, the Pikas, Porcupines, Gophers, Sewellels, Beavers, Squirrels and Marmots, the Pocket Mice (Family Heteromyidae), Jumping Mice (Family Zapodidae), and Rats, Mice and Lemmings (Family Muridae). The great majority of the species of rodents in this country belong to the last three-named families.

POCKET MICE The Pocket Mice are mainly found in the dry areas of southwestern and western United States and Mexico. Two different types of animals are found in this family, the True Pocket Mice as represented by the Plains Pocket Mouse (Perognathus flavescens) and the larger Kangaroo Rats as represented by the Ord's Kangaroo Rat (Perodipus ordi). The former is a mouselike creature about five inches in length possessing rather coarse hair, external cheek pouches like the gophers, burrows into the sandy ground, remaining there during the day as it is strictly nocturnal. The Kangaroo Rat is about ten inches in length, possessing immense hind legs and a long brushy tipped tail. It is also nocturnal in its habits.

JUMPING MICE These mouselike creatures are found in northern parts of North America in areas from Labrador to as far south as North Carolina and extending westward in Iowa. There are many marked differences between members of this family and the true mice, the important ones being the possession by the former of a very coarse fur, a long tail, extremely long hind legs, a kangaroolike appearance and the habit of jumping. Two kinds of jumping mice are recognized, the several varieties of the Meadow Jumping Mice and many varieties of the Woodland Jumping Mice. The latter are found in woods and mountainous areas, avoid man, and differ from the former mainly in the richness in color. The Meadow Jumping Mice are found in fields and meadows, subsist on grass seeds, berries, etc., bring into use their powers of leaping when threatened, and are usually less intelligent than the commonly observed mice. They are harmless, inoffensive, and most frequently they offer but little resistance when handled. They are very agile and possess a muscular strength of enormous power for so small a creature. Unlike most species of mice, the jumping mice spend the

winter and the months other than the warmer ones in a state of hibernation curling up in their nests underground.

RATS, MICE and LEMMINGS (Family Muridae)

This family contains the largest proportion of the mammalian fauna, which are found over the entire globe. They are the most typical of the members of the rodent tribe, and, with but few exceptions, species in this family are known as rats and mice. These two terms in their original sense were employed for the two semi-domesticated species, the house mouse and the Norway rat, but have become established for wild species of ratlike and mouselike rodents whether they do or don't belong to the same genus as the house mouse. Zoologically, rats and mice do not constitute different genera or groups, the difference has only to do with size, the mice being the smaller of the two. Mice are small rats and rats are large mice. It may be that rats look upon mice as a distant relative rather to be ashamed of.

This family is divisible into many sections, the most important sub-families found in this country being the (1) Meadow Mice, Lemmings and Muskrats (Microtinae); (2) American Long-Tailed Mice and Rats (Cricetinae); and (3) the Introduced (semi-domesticated) Mice and Rats (Murinae).

LEMMINGS

The name Lemmings originated from the associations of this rodent in the barren mountains of Norway, Sweden and Arctic regions. Popularly these rodents are not thought of as being related to mice. In appearance the Lemmings bear such a close resemblance to the common field or Meadow Mice as to make it a difficult task to draw a sharp distinction between the two. The North America Lemmings are usually associated with the Arctic regions and are found in barren grounds from Labrador to Alaska. The Cooper's Lemming Mouse (Synaptomys cooperi) is one of the few species which may be found in areas from New England to Michigan and Indiana and at times as far south as Virginia and the mountains of North Carolina. This rodent is about five inches in length, possessing a very short tail, rather coarse hair and is usually recognized by its grooved upper front teeth. As far as known they subsist on roots and grasses. They are very agile. Another species closely related to Cooper's Lemming Mouse and which is found in Dismal Swamp, Virginia, is the Dismal Swamp Lemming Mouse. Most all other species are to be found in northern New England, Canada and districts further north.

RED-BACKED MOUSE (Evotomys Gapperi)

There are several varieties of this little mouse which is closely related to the Meadow Mouse, but possessing a longer tail and recognized by its chestnut color. By some it is erroneously referred to as the Wood Mouse, for it is usually to be found in the woodland clearings, building its nest under a log or sometimes it lives in dense patches

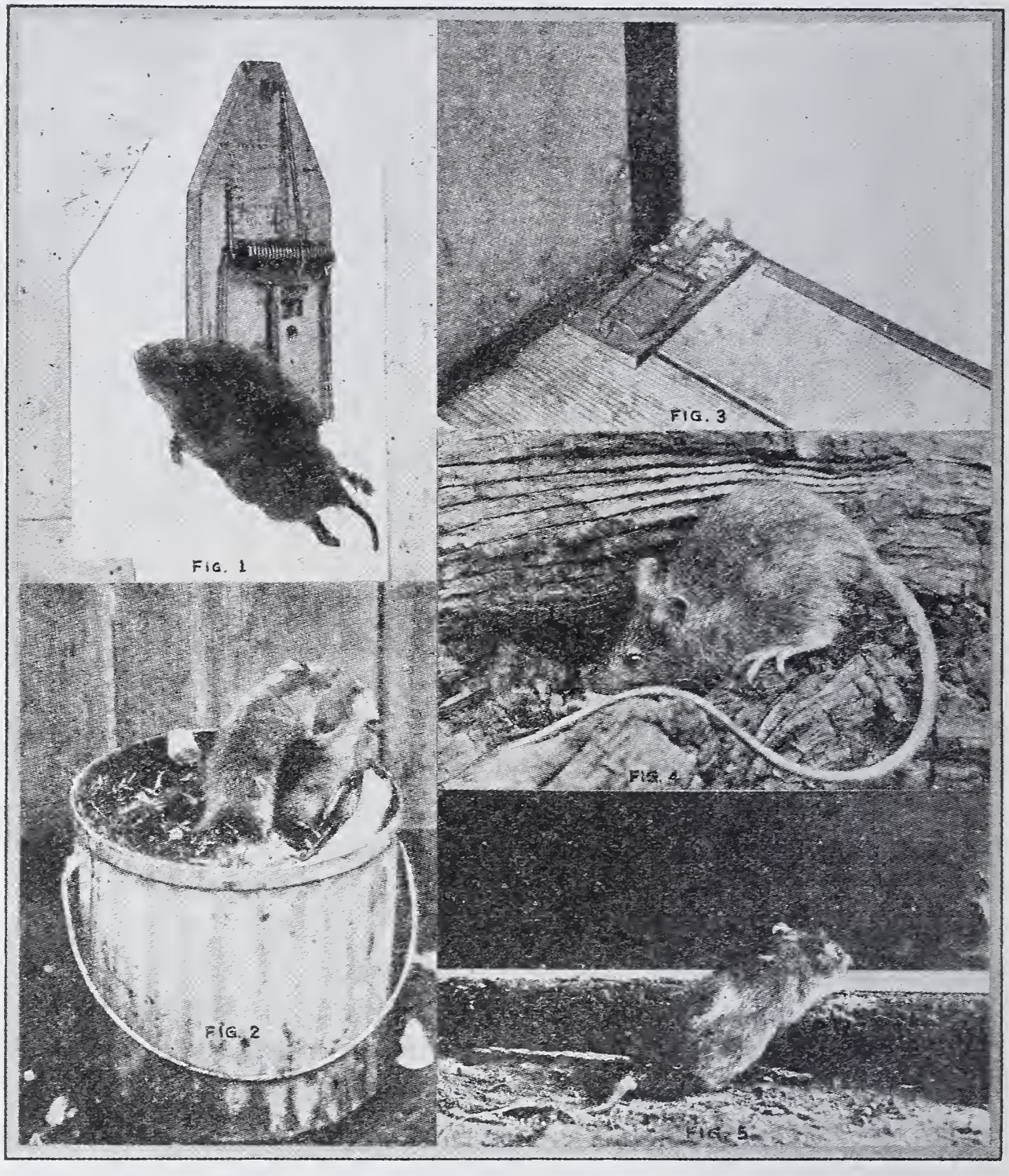

Fig. 1 Spring Trap.
Fig. 2 The Open Garbage Pail—a Typical Rendezvous.
Fig. 3 Trap, Properly Set.
Fig. 4 The Long-Tailed Rat.
Fig. 5 Filthy Corners, Dirt-Laden Crevices, Where Rats Delight to Cavort.

of grass. The important varieties, which differ between each other in exhibiting some slight peculiarity in general appearance, are the Carolina, New Jersey, Pallid, Labrador and Ungava Red-backed Mice. Their range is from Labrador to the mountains of Pennsylvania and the cold cranberry bogs of southern New Jersey, and in the case of the Carolina species, the latter is to be found in the mountainous areas of North Carolina.

MEADOW MICE OR VOLES OR FIELD MICE (Genus-Microtus)

There are many species (about fifty) of this genus in this country. The most familiar members are the Meadow Mouse (M. pennsylvanicus) found in areas from southern Canada to North Carolina and westward to the edge of the plains; the Black Meadow Mouse, found along the coast of Virginia and North Carolina; the Gull Island Mouse, found in New York State; other varieties found in Labrador and Canada; the Prairie Meadow Mouse, found in the Upper Mississippi Valley; and several varieties of the Pine Mouse (M. pinetorum) found in the New England, Middle Atlantic and Southern Atlantic States and in the lower Mississippi Valley. They are short (six inches) chunky mice with small eyes, short legs, and very short ears which are almost invisible, being concealed by the thick fur. The color of the upper parts of their bodies varies considerably. They are most frequently found about marshes and wet meadows and even on the salt marshes near the sea. They inhabit meadows, pasture land, orchards, gardens, corn fields, and wherever grass is left uncut. They run on the ground or burrow into banks, often devastating whole fields with their burrows, ruining crops, cutting off grain close to the ground, and damaging vegetables, plants and fruits. They cause an annual loss to crops, nurseries and orchards amounting to many millions of dollars. They are nearly as prolific as the house rats and they are not as agile as other mice.

MUSKRAT (Fiber Zibethicus)

The largest of the North American rats (average length is two feet) and the one possessing some economical value is the muskrat, a water-abiding animal, whose fur is very popular. This is the most important aquatic representative of the mouse family. Like the beaver, the muskrat is a home builder, constructing large dome-shaped cabins in the marshes, which are visited mainly when the water is high and in winter. There are several closely related varieties of muskrat found in Labrador,

Newfoundland, eastern North America extending southward to Virginia and the middle Mississippi Valley. In appearance, they look very much like large meadow mice, with muscular, flat, scaly tails. The fur is a rich shiny brown with a pale not too dense underfur appearing like silk. The musk, which gives this rodent its name, is very powerful and is contained in two flat, oval discs about an inch in length located between the hind legs beneath and to be seen when the skin is stripped off.

AMERICAN LONG-TAILED MICE AND RATS (Cricetinae)

In this family are to be found several species and varieties of the Wood Rat (genus, Neotoma); Cotton Rat (genus, Sigmodon); Rice-field Mouse, known also as the Rice Rat or Marsh Mouse (genus, Oryzomys); Harvest Mouse (genus, Reithrodontomys); and the White-footed Mouse, also called Deer and Wood Mouse (genus, Peromyscus).

The Wood Rat found in the Hudson Highlands along the Alleghenies, in the low Mississippi Valley and western Florida, is a large (sixteen inches) colored rodent possessing prominent ears and a tail almost as long as the body. The fur is soft and thick, as found in a squirrel. These rats inhabit rocky ledges or caves in mountainous areas.

The Cotton Rat differs from the other members of this family in that its general appearance resembles that of the meadow mice but it is quickly distinguished from the latter by the long tail. This rodent inhabits the southeastern Atlantic States and the Gulf coast up to Louisiana. It burrows and constructs underground nests in deserted fields, rice plantations or it may be found along hedges and ditches.

The Rice-field Mouse, mostly aquatic in its habits, is found frequently on the banks of rice fields in the southern part of our country, chiefly in Florida, though it may be observed in dry areas and in territories as far north as New Jersey. It looks like a young brown or Norway rat, but is easily distinguished by the longer tail.

The Harvest Mouse is a small (five-inch) rodent, russet brown in color, possessing a long tail and grooved incisor teeth, which distinguishes it from other long-tailed mice. The several varieties are to be observed in grass fields of the southern states.

There are many species and varieties of white-footed mice, found in all parts of the country. They are beautiful, gentle rodents, mak-

ing their home in the woods. They may devour young birds or usually collect nuts, berries and grain, finding their way frequently in farmhouses and granaries in search of food.

INTRODUCED RATS AND MICE (Murinae)

The terms rat and mouse are probably used most frequently to designate rodents of this sub-family, the former term being applied originally to the British mammal known as the Black Rat (Mus rattus) and now also applied to the cosmopolitan rodent, the Norway (common or brown) Rat (Mus norvegicus). The word mouse is used most frequently when referring to the cosmopolitan, semi-domesticated House Mouse (Mus musculus). Exclusive of tail, rats may be said to vary in length from four and one-half to ten inches or more, while mice measure from two to four inches. The scientific term Mus was and still is employed as the designation for both rats and mice, even though it was proposed to use the name Epimys for the larger forms, the rats, and reserving Mus for the smaller forms, the mice. The term Norway rat is designated by Mus norvegicus and the house rat by Mus rattus. The former is the common gray or brown rat and the latter is the black rat (or the gray form Mus rattus alexandrinus) which is the first species described in Europe. The genus Mus (known frequently as the Old World genus) contains over 300 species found the world over and of these only forty-five species may properly be termed mice and the remainder rats.

The following four are the only species which are of greatest interest in this country:

Mus musculus—common house mouse.

This is a cosmopolitan rodent found throughout the entire old world, North and South America, and usually not found in cold regions. The general color is gray and it averages about six and one-half inches in length.

M. rattus—the old English black rat.

This species is slender, averaging fifteen inches in length and possessing a pointed head, large thin ears, and a tail always as long or longer than the head and body. It has a glossy, bluish-black color, but sometimes grayish, and is cosmopolitan though it is rare in areas where the Norway species is to be found, as it is unable to cope with the latter.

M. alexandrinus is similar to M. rattus in all respects except the color is gray.

This species is a native of Egypt and adjacent countries and has been introduced into all parts of the world where warm climates prevail. This species, known also as the roof or snake rat, is common in South America and it inhabits many parts of our southern states, especially those bordering on the coast.

M. norvegicus—also known as the common, house, barn, wharf, gray, brown or Norway rat, formerly was spoken of as Mus decumanus. It is larger, stronger, more robust, more ferocious, more prolific, and differs in habits from the previously mentioned species. This species is more of a burrower, living in excavations which it makes under buildings and in soil along the river banks, stables, in feed shops, warehouses, markets, sewers, on farms, etc. It quickly displaces all other species and is therefore to be found most commonly in thickly populated districts. The only reason why the house mouse can hold its own against this species the brown rat, is due to its ability to escape into retreats too small for the brown rat to follow. The latter is a heavily built rodent, approximately eighteen inches in length, possessing a thick head and a tail always shorter than the head and body, short rounded ears and a dull brown color.

NATURAL HISTORY OF THE RAT

The Hebrew word, akbar, refers to a small gnawing animal or rodent, either the mouse or rat. Biblical reference of this rodent is to be found in Leviticus 11:29, when the Lord speaking unto Moses and Aaron and advising them to inform the children of Israel as to the beasts which they shall eat, says, "These also shall be unclean unto you among the creeping things that creep upon the earth; the weasel and the mouse, and the tortoise after his kind." The mouse is also mentioned in Isaiah 66:17 and in I Samuel 6:4, 5, 11, and 18.

At one time the rat occupied a comparatively small part of the Old World, but now, through the many facilities of transportation, it is present in all parts of the globe. Its fecundity, cunningness and adaptability to almost every kind of environment have enabled it to flourish and secure a foothold almost everywhere.

It is of course impossible to obtain an exact and complete history of the early migration of the rat. Perhaps archaeological studies in the future will give us this information. The records up until about the twelfth century are scanty and indefinite. We do know that the house rat (Mus rattus) did arrive in Europe about the twelfth century. Giraldus Cambrensis (who died in 1220) records several anec-

dotes concerning this pest. It was this species which caused the great plagues before the eighteenth century and it is the rat of the legends of the Pied Piper. Though the Mus rattus is still prevalent in Europe in a number of scattered localities and in northern United States and Mus rattus alexandrinus is more frequently found in the southern states and localities where the climate is warm, we find that the Norway rat (Mus norvegicus), the more pugnacious and powerful species has followed the earlier species and soon became the dominant form. Though the black rat has not been completely exterminated, surviving in small numbers, the Norway species has spread so rapidly and is to be found in such large numbers that many people are under the impression that this species has completely displaced Mus rattus. The arrival of the Norway rat on the continent of Europe is usually given as around the year 1727. Its original home was some portion of Central or Southern Asia, either India, China or Persia. Conrad Gener describes this species of rat in his "Historia Animalium," which appeared in 1553. During the year 1727 a famine raged in India, many severe earthquakes visited Persia and adjacent countries, so that it is possible the brown rat was driven in huge swarms westward and that these several circumstances combined to bring about this invasion of Europe by the Norwegian rat. England, the "Mistress of the Sea," aided in the spread of the latter species over Europe, by means of her ships, which through their journey around the world became infested. By the beginning of the nineteenth century almost all of continental Europe was invaded, even spreading into the northern parts of Scandinavia, and cold regions, the rodents settling in buildings rather than in the cold open spaces.

The north Atlantic seaboard of the United States was invaded in 1735 by rats that were brought in on English ships. Records around the year 1775 describe the presence of this pest. For almost a century these rats had not spread far beyond the coast, but by the beginning of the twentieth century they had spread over the whole country and Canada, except along those regions where cold may have barred their progress. So you see that rats have been introduced into our midst from foreign countries. The more civilized we have become, the more modern and quicker was our means of transportation. Thus the more quickly did the rat invade all territories, due to this multiplication of commercial transportation facilities. Immigration and emigration is perhaps as common among rats as with members

of the human race. As stowaways, they are to be found on almost every means of conveyance. Every vessel, freight train, automobile and even the camel and ox teams may have their humble few or even a cargo of mice and rats, which may find themselves in Florida during winter or in Maine or Europe during the summer months. In fact, man's scientific means of controlling the rat is offset somewhat by the modern means of travel which the rat also uses. They thus gain a foothold in a new territory, which may be the sub-basement of a department store, the tenth floor of a skyscraper or the mere confines of a log cabin. Here they more than likely will not find the presence of their natural enemies which they have left behind. They then begin to multiply and show us how the mathematical formula of geometric progression actually appears when put into practice.

HABITS AND REPRODUCTION OF RATS

Rats are chiefly nocturnal and therefore exact information concerning their habits may not be so well known or as detailed as one would expect to find when considering the life history of a rodent so commonly observed. Rats seem to have defective vision by daylight. Their sense of touch and smell is however extremely delicate. Rats depend more upon their noses and ears than upon their eyesight for obtaining their food and avoiding their enemies. These rodents are very cunning and "as sly as an old rat" is a true adage. They are quick to gather experience and learn to avoid dangers. Climatic conditions and the food supply affect markedly the number of litters produced annually and the number of young brought forth in each litter. In warm areas and with an abundant and favorable supply of food, the frequency of breeding and the numbers brought forth each time increase as compared with conditions in cold regions. Well-fed rats mature quickly, breed often and have large litters. In temperate climates they breed on an average from three to five times a year and bring forth from six to twenty young, which are usually to be found in nests in underground burrows or under cargo, wood piles, floors or other shelter. The period of pregnancy is about twenty days. The young are naked and blind, and though they are in an apparent helpless condition they are able to shift for themselves within a few days. They grow rapidly, and though they do not attain full development until they are eighteen months of age, the females are capable of breeding when three to four months old. The black rat and the roof rat are not as prolific as the brown rat. A couple of

rats, if left to multiply, will become, under favorable conditions, the ancestors to many hundreds of offspring in the course of eight to ten months. An estimate of the rat population in this country and continental Europe is that it at least coincides or may be slightly larger than the human population. In tropical and semi-tropical countries, the rat population is incredibly large and is many times the human census.

When we remember the rat's capacity to reproduce, we cannot feel and wonder that if man did not devise means to maintain the balance between himself and the rat, our own future survival would be uncertain. In spite of all measures to eradicate them, rats are still numerous and as mentioned they are present in numbers as great or even possibly exceeding that of the population of our country. The struggle to diminish their numbers, let alone to eradicate them, will require all the resources of science, if man is to win out.

Sudden migrations and invasions of rats have been known and have been recorded even in our own countries within the past thirty years. This does not take into account the seasonal movements from houses to barns and open fields during the warmer months, or the return movements when cold weather appears. These migrations are probably instances of enforced moving due to a lack of food in a locality or to other natural disturbances, as earthquakes, etc. The large migrations are similar to the smaller ones we may find in dwellings which were heretofore free from these pests, becoming infested due to the raising of several large buildings and the emptying of other dwellings in the same neighborhood. During war time we always find rats leave an evacuated village, for there is no food for them.

The brown rat is more apt to be found on the ground or in cellars or close to the latter, while the roof and black rats do not burrow but, being more agile climbers, are apt to be found living in trees or in walls and in spaces near the roof. The latter will also climb over pipes, wires, cables, rope, etc., and gain access to the uppermost part of any structure. The Mus norvegicus is a burrower and though not addicted to climbing and swimming, it can do both. The depth to which it will burrow under natural conditions is usually not greater than one and one-half feet, though some have observed that this may reach two and one-half feet. Whether gnawing or burrowing, it has been found that this rat can also penetrate clay, mortar and even soft brick. The brown or house rat is very

cannibalistic. The adult male species will eat its own offspring though the female will defend the latter.

Wild mice, lemmings and voles are subject to very violent and at times marked fluctuations in numbers in northern regions. This periodic ebb and flow occurs regularly in certain localities every three or four years. After the rodent increases until the uppermost point in this four-year cycle, disease then appears. The mouse population is attacked and there results a rapid decline in numbers. Universal epidemics are not always the cause of the decline. There is a strong indication that some cycle of climate prevails and is in action when this condition is evident.

Abnormal congenital deficiencies of coloring matter resulting in the appearance of a white color (albine) and abnormal developments of dark coloring matter (excessive darkness; melanism) are to be observed among all species of rats. Mottled forms are also common. Rats (even wild) adapt themselves readily to the conditions of life in captivity. Rats have courage and are extremely intelligent. Sewer rats are usually larger than the rats commonly observed. Their life is very secure in such a retreat. They have no hawks, owls, weasels, snakes, dogs, cats or other natural enemies to worry about and they can flourish and multiply to their heart's content.

FEROCITY OF RATS

The brown rat, though formidable against other species of rats, will not bite human beings wontingly. Such occasions are indeed rare and many of these tales of being attacked by rats are merely interesting stories to relate. If cornered and attacked the rat will bite but the bite is not poisonous. Secondary infections, some of which may prove serious, may however occur, just as would be the case with bites by any other animal or wounds caused by any implement. When food is lacking all species of rats, but especially the brown rats, become cannibals and this frequently accounts for the reductions in numbers of rats in certain areas. The brown rat, being the most formidable of all other species, displaces the latter wherever it gains a foothold. Whether this species actually kills the others or the latter die on account of disease spread by the brown species is of course not always possible to determine. The only reason that the black and roof species are found in tropical areas in appreciable numbers is due probably to the arboreal habits of these latter two species.

FOOD REQUIREMENTS

The brown rat eats animal as well as vegetable food of all kinds (omnivorous). Almost anything will comprise its menu and this accounts for the ease with which it adapts itself to almost any environment. Eight to ten adult rats can consume about one pound of grain in addition to damaging or rendering unfit an equal amount or many times this quantity. Can you then appreciate the enormous bill which we pay just for the feeding of this pest without even considering the cost of the material they attack and spoil? Rats resemble squirrels in that they can hold their food when eating, sitting up, with the back arched, the piece of food being turned and held in the paws. They drink large quantities of water, and they drink at frequent intervals.

Rats are our competitors for the world's food supply. Who will gain the upper hand in the possession of the earth will depend in the last analysis on which creature can get rid of the other and will be more efficient in securing his daily ration.

DAMAGE AND ECONOMIC LOSS CAUSED BY RATS

Who can tell the exact loss caused by rats? First and foremost let us remember that the rat is a permanent menace to public health. Let us not diminish our vigil due to the fact that an epidemic of plague has not been recently within our midst. In time of peace, we must be prepared to war against these traveling agents of deadly organisms, for if we wait until an epidemic drives us to institute a campaign of destruction against the rat, we may find that we have waited too long.

Other than the fact that the rat may be the chief factor in the spread of disease, especially bubonic plague, and their destruction will minimize the danger of the spread of the latter, there is an economic side to the rat problem. The toll of human life would be a large enough expense should plague gain a foothold in any environment. Can you however realize the loss of money which would result due to the commercial prejudice against a plague-infected port or community? The rat's depredations are unlimited. It levies a ruinous toll upon agriculture, commerce and industry, and in the home.

It is impossible to obtain or even estimate approximately the damage caused by these rodents. Attempts have been made in foreign countries to collect such statistics. England estimated that the damage done in Great Britain and Ireland is approximately seventy-five million dollars annually; Germany claims an annual loss of fifty

millions; and France a loss of forty million dollars annually. The loss in this country is estimated as a minimum of one-half billion and probably reaches closer to a billion dollars a year.

In the United States we find that the cultivated grains, the favorite food of rats, undergo a heavy loss due to injury by these rodents. Indian corn and the small grains, as wheat, oats, barley, rye, etc., during all stages of growth and when in storage, are constantly being attacked by rats, resulting in a serious financial loss. Malt, rice and the sugar cane experience serious loss from rat depredations. Rats are destructive to poultry and game preserves, destroying their eggs as well, whether on the farm or in the bin at the corner grocery store. Rats attack all fruits and vegetables whether on the farm, plantation or in storage. Rats attack all parts of the growing plant and they are therefore a menace in the greenhouse and to the florist.

The loss caused by rats to grains, plants, fruits, vegetables and foodstuffs in the home, warehouse or market is serious, but of equal importance is the loss caused by rats in the destruction of books, all dry goods, leather goods, lace, fabrics, carpets, mattings, etc. Here one finds that the loss may be due to the fact that the articles are rendered unsalable, having been soiled by rats or due to injury of the articles caused by the rat gnawing at them either to secure material for their nests or to obtain food as may be found in the glue and paste in the bindings of books or the starch in linens. Rats carry away many valuable articles which they use in building their nests.

Rats, by their gnawing, seem to be able to penetrate almost any object unless it is constructed of concrete, hard brick, stone, glass, iron or tin. Even lead and zinc pipes have been gnawed through by rats, causing water and gas leaks and subsequent damage which may be considerable. Wooden tanks have been so damaged by rats as to be made unusuable, causing much loss. Burrowing into embankments and dams, through beams supporting tanks or under other foundations, and through plaster in the walls of buildings, they have weakened or even undermined structures which have resulted in serious damage and subsequent heavy financial losses. In money, the approximate loss of merchandise and foodstuffs caused by depredations of rats and mice amounts to enormous sums. Rats have been known to attack other animals, especially pigs, or occasionally the hoofs of horses. Mice chewing matches in cupboards and rats eating insulating material from electric wires, resulting in short circuits,

and in both instances in the all too frequent production of disastrous fires and even explosions after gnawing into gas pipes have resulted in serious loss to property and at times in that of human life.

VALUE OF THE RAT

The house rat renders no important or significant service to man. The statement is made by some that rats serve as scavengers, but it is to be remembered that we have safer, cheaper and more satisfactory sanitary methods for the removal of dirt and filth than to breed rats for such purpose. This pest attacks our purse and our health, causing so much injury as to call for reprisals.

Of the many rodents, we must remember that the muskrat has been one of the chief factors in maintaining a high total value for our annual fur production. This species is fortunately one the destructive habits of which are of concern only in restricted areas. The injury to grains except rice by the muskrat is generally slight. Its most serious offense is the damage to dams and embankments and to fish. Means of protecting successfully embankments and dams, as well as vegetables, gardens and small ponds are available so that these may be safe from attacks by muskrats. Taken as a whole, the economic value of muskrats outweigh considerably the harm produced. In certain sections of the country the meat of muskrats is employed as a food.

The skins of certain species of moles have been fashionable in this country. Moles are very destructive in many localities, and methods of killing or trapping and exterminating these pests have been practiced. As a by-product of this trapping, the skins have been collected and used for articles of adornment or for the making of garments. Though in some European countries moles have been trapped purposely for their pelt, in this country extermination is mainly practiced because the pests are troublesome and the use of moleskins by fur manufacturers is only incidental.

THE ROLE PLAYED BY RATS IN THE DISSEMINATION OF DISEASE

Great as is the economic loss caused by rats through the destruction of large quantities of foodstuffs and other material, it can bear no comparison to the loss caused by this pest to the health and welfare of man and other animals. It cultivates and spreads disease producing micro-organisms and it is actually one of the greatest traveling agents of the organisms of death. Who can tell what the rat

has done to the human race throughout the ages in the part played by this mammal merely in the dissemination of bubonic plague (black death) without considering other diseases which it spreads?

PLAGUE

Inasmuch as it is now possible to hope that mankind may, to a very great degree, be freed from certain age-long terrors and in particular the dreaded plague, it is to be remembered that unless we are prepared at all times to control the influx of rats, a great epidemic of this pestilence may appear and wipe us out.

In the medicine of the Old Testament mention is made of the bubonic plague and there is a relationship mentioned between this pestilence and the rat (see I Samuel V, 6; VI, 4-5) when we hear that 3000 years ago the Philistines were smitten with the plague during a war with the Israelites. The plague raged during the days of Pericles, that great ruler of Athens who died in 428 B. C. This pestilence prevailed throughout the Roman Empire between the years 164 and 180 A. D. in the reign of the Emperor Marcus Aurelius. At the close of the second century A. D. China was struck by this dreaded terror and plague waves were observed during the time of the Emperor Justinian (527-565 A. D.) in the Eastern Empire and of Pope Gregory I the Great (590-604) in the west. In 543 ten thousand people died in one day in Constantinople. In England four epidemics were recorded in the years 664, 672, 678 and 683.

Ibn Sina or Avicenna (980-1036) called the "Prince of Physicians," who was one of the celebrated physicians, naturalists and writers of his time, recognized a connection between rats and plague during the outbreak of this pestilence in Mesopotamia and refers to the fact that on the approach of the plague mice and other underground animals leave their subterranean environment and are found moving about in a staggering manner. In the "Bhavagta Purana," written more than 800 years ago in Hindustan, mention is made of the relationship between rat mortality and plague and the inhabitants are instructed to vacate their dwellings as soon as they notice a mortality among rats.

The Black Death, the Great Mortality or the King of Terrors during the fourteenth century came nearer to the extirpation of mankind than any other pestilence or evil. This fourteenth century pandemic started in central Asia or southern Russia and by way of Crimea and a Genoese ship, Genoa and western Europe was

reached. It passed through Armenia to Asia Minor, Egypt and north Africa, and finally the plague arose in 1348 in England. Two-thirds of the student body at Oxford and between one-quarter and one-half of the whole population perished. It was estimated that twenty-five millions was the death toll in Europe, and thirteen millions perished in China when the pestilence spread eastward, while other estimates are that one-fourth of the population of the earth or over sixty millions of human beings were wiped out. The Decameron of Boccaccio gives one of the most graphic accounts of this pandemic. It was described in minute detail by other writers. Artists who were witnesses of the Black Death in this and other pandemics have given us some of the horrors of this terror in the pictures they have painted. Among these portraits are "Peste de Marseille," by Francois Gerard; "La Peste dans la Ville de Marseille en 1720," by J. F. De Tory, the Younger; and the famous picture, "Les Pestiferes de Jaffa," by Baron Gros, now in the Louvre. It was this epidemic that led the Venetian Republic to institute public health regulations among which was the quarantine, to exclude infected and suspected ships and to isolate travelers from Levant in a detention hospital for forty days. The choice of the length of time for the period of detention is of biblical significance in that Moses and Christ had both remained isolated in the desert for that number of days.

Cases of bubonic plague present in all countries throughout the centuries which followed developed into another pandemic during the seventeenth century which, though it did not sweep over all Europe, struck certain areas with terrific force. England was visited in 1603-1665. In 1665 London lost 69,000 of its people. The story of it is told in Defoe's Journal of the Plague Year. It was the great fire of London in 1666 which brought an end to the plague in that country, for by destroying infected rats, the fire accomplished more than what men were able to do. Moscow lost 127,000 of its inhabitants during the Russian visitation of the plague in 1601-1603. France was attacked in 1608-1668; the Netherlands in 1625-1680; and Italy in 1630-1691. The Italian epidemic accounted for 80,000 victims in Milan, and over a half million in the Venetian Republic. The victims of the plague in Vienna in 1679 numbered 70,000 and in Prague in 1681 there were 83,000 deaths. Practically all the important countries were finally reached and all were severely ravaged.

In modern times bubonic plague has raged in oriental countries, causing for many years in India an average of nearly one million

deaths annually. In China epidemics have been almost constant until but recently. It was during the Hongkong epidemic in 1894 that the causative agent of the disease, the Bacillus or Pasteurella Pestis, was isolated. This very serious epidemic, starting in China, spread through Bombay to other parts of India, then to Madagascar, into the Malay and Philippine Islands and other islands of the Pacific, thence through North America, South America, Europe, and in 1900 it appeared in Cape Town and on the British Isles. At least seven million British subjects succumbed within seven years. These descriptions give one but a slight conception of the ravages by this pestilence in former days.

In our own country during the early part of this century (or in 1903) the disease was prevalent in San Francisco and for several years up until 1908 human cases of bubonic plague appeared. The disease never took on the menace of an epidemic due primarily to the energetic efforts of the Marine Hospital Service (now the United States Public Health Service) experts who, even though the local authorities were not in complete agreement with the federal workers due to political and economic reasons, instituted thorough methods of rat extermination, rat proofing, and other necessary sanitary measures. We have here a practical example of a city being made rat proof, so that in this instance the sacrifice of human life to the plague was limited to less than two hundred. More recently foci appeared in Texas and New Orleans.

The countries in the Far East are always a potential focus or nucleus for the spread of bubonic plague and it is only due to the concerted efforts of the health authorities in European and American countries that epidemics of this terror have been kept from their shores. The ravages of the most serious epidemics are very quickly forgotten during times of security, but it is best to be prepared at all times to combat an increase in the numbers of rats, thus gaining assurance that a nucleus for the spread of plague will be impossible. Just twenty years ago sixty thousand deaths occurred due to the epidemic in Manchuria and in 1918, 20,000 more fatalities occurred in the same area. There are deaths constantly reported in Asiatic and African countries and especially in India. Just as the new year appeared last month, we find the newspapers flashing a report of a small epidemic appearing among members of the Douiret tribe in Tunis.

As mentioned previously, the casual relation between the large numbers of dead rats and the appearance of plague was observed at a very early period, but it is only during modern times the observation was made that plague is a bacterial disease of rodents and especially rats and which is commonly transmitted to man by fleas. The fleas now themselves infected leave the dying rat, infest man, whom they bite, depositing on the skin of the new host infected regurgitated material or feces or both, thus inoculating him at the same time with the causative agent of plague. The latter, the Bacillus or Pasteurella pestis, was described simultaneously in 1894 by Kitasato, the famous Japanese investigator, and Yersin, a Frenchman, both working independently. Kitasato's paper preceded Yersin's by about three weeks. In 1897 Ogata found plague bacilli in fleas from rats dead of bubonic plague. In 1898 Simond carried out successfully the transmission of bubonic plague by the rat flea, these experiments being confirmed by Verjbitski in 1903 and by Liston in 1904. The rat-flea-human method of the spread of the disease was most conclusively demonstrated by the British Plague Commission in India. It is with this knowledge that we know to abate an epidemic of plague the essential feature in any program of prevention is the keeping out of infected rats, for to attempt to stop plague by treating the sick would, even with our methods of immunization, etc., be an almost impossible task in the wake of billions of infected rats allowed to multiply and carry on unmolestedly. Other rodents, even marmots and the Siberian tarbagan, but particularly squirrels, are frequently important factors in the perpetuation of plague and its subsequent transmission to the human family, but the rat, on account of its greater numbers, its ubiquity and its more extensive traveling power, is the most potent factor.

In man, plague, the most dreaded of all scourges, manifests itself in three forms: (1) bubonic (or glandular) plague, which is characterized by carbuncles, glandular swellings known as "buboes" (therefore the term bubonic) and hemorrhages from mucous surfaces and beneath the skin this appearance causing the disease to be known as "black death." (2) Pneumonic plague, a highly fatal form, appears with the usual characteristics of an inflammation of the lungs or a typical broncho-pneumonia. The sputum is usually hemorrhagic (bloody) and laden with the causative agent of plague (Bacillus pestis). This form is transmitted from man to man, generally by contact with material soiled with the sputum or inhalation of the

sputum spray because of close contact with infected individuals. (3) Septicemic plague commences with immediate overwhelming symptoms, hemorrhages under the skin are numerous (these turning black whence the name "black death") and death occurs within a few days. The important problem in the prevention of this disease is the extermination of plague-infected rats, ground squirrels and rodents and the destruction of and protection against fleas.

TRICHINIASIS OR TRICHINOSIS

Trichinella spiralis or the trichinia worm is a whitish, slender and tapering animal parasite about one-eighth inch long, which may be found in quite a large number of animals, but in this country, hogs, rats and man are most susceptible. The adult trichinia is found in the intestines of the infected host, gaining entrance through the digestive tract as larvae encysted in meat. The worms are soon freed from their cysts and take refuge among the folds of the mucous membrane of the small intestines, where they mature and copulate. Trichinia worms are of interest in that they bring forth living young, free of the eggshell. They retain the eggs in the uterus until they hatch and this may occur as early as within a week after the adults were swallowed. The young are usually deposited directly into a lymph or bloodvessel and the larvae are thus distributed throughout the body. They may migrate and be found in all tissues but are incapable of developing in any environment except muscle fiber, the muscles particularly favored being those that are active and rich in blood and oxygen. There soon results a degeneration of the infected muscle fiber followed by the formation of connective tissue cysts around the young worms. Usually only one or two worms are enclosed in a cyst, but as many as six or even eight have been observed at times. The disease caused by trichinia worms (Trichiniasis or Trichinosis) is more fatal to man than to other animals, the fatality rate being as high as 25 per cent. or more. During the course of the disease there is a constant fever (a symptom which is characteristic to trichinella and unique among worms) and other symptoms are so much like typhoid fever that the latter is frequently given as the diagnosis.

Man usually becomes infected from eating pork contaminated with large numbers of the worms and which is eaten either raw in the form of sausage or "wurst" or if cooked, the heating process was not thorough. Hogs become infected by the ingestion of trichinous meat of an animal, either as waste scraps of pork, carcasses of other

hogs, or devouring food contaminated with infected rat excreta or what is the chief source of danger, the hog eats the dead bodies of infected rats and mice. Rats in localities where an epidemic of trichiniasis prevails are usually extensively infected. Around slaughter houses and stables, where hogs are found, of all rats captured, 75 per cent. and even as high as 100 per cent. of these pests will be found trichinized due to their eating trichinous meat or food contaminated with infected dejecta. In countries as Germany and probably Italy, where pork is eaten raw, the first step taken to break up an epidemic of trichiniasis is by starting a campaign to destroy the rat, thus breaking the important connecting link in the chain which makes an epidemic of this disease possible.

It is perhaps this worm and the tapeworm which were responsible for the ancient Jewish law against the eating of pork. Epidemics in this country are usually among people in the foreign quarters who still cling to their native dishes which employ raw pork. Infected raw sausage and raw ham, usually home-made, and which have not been cured properly, are the great offenders. The important and assured preventive measure against trichiniasis is the abstinence from all pork which is not thoroughly cooked. Within the past month some eighty odd cases of trichinosis appeared in California, in particular in the cities of San Francisco, Alameda and Oakland, even though all sanitary safeguards commonly practiced have been instituted. This small outbreak again brought to the attention of the public and sanitarians the fact that swine come to slaughter infected with trichinia worms. The disease is difficult to detect in these animals, and meat from the latter reaches the market with the presence of trichinia worms not having been recognized, unless the product came from an establishment where care is observed in packing and treating meat, and which is under Government inspection. Local pork slaughtering, where federal supervision is wanting, and not carefully inspected by the local health authorities, and home-made pork products are most frequently responsible for the appearance of this infection in man.

Today we hear of two deaths and twelve other seriously ill people all diseased with trichinosis in Wayne, Pa., near our own city. These cases were reported in individuals who participated in the eating of bacon, scrapple and sausages prepared from a pig bought from a neighboring farmer and butchered privately. An investigation disclosed the presence of trichinia worms in the flesh of the swine which

was killed and used in the preparation of these products. I must again emphasize the need of avoiding all but well-cooked pork if we are to expect to see a disappearance or at least an infrequent appearance of trichinosis.

OTHER DISEASES DISSEMINATED BY RATS

Rats have been shown to serve as a reservoir for the spirochetes (Leptospira ictohaemorrhagiae), causing infectious or epidemic jaundice, Weil's disease or icterohaemorrhagic fever, an infection occurring in Europe and Asia and reported from various parts of North America. During the great world war many cases were reported at the front in the trenches. The organisms are commonly found in rats, especially in the kidneys, being constantly excreted with the urine. The rats themselves are not apparently attacked by the spirochetes. That mice and rats serve to spread Weil's disease appears evident from the common occurrence of epidemics in those environments where rats are abundant. The disease is transmitted to man, spirochetes gaining entrance through abrasions of the skin or by mouth from contaminated material. It may be that infected soil also plays a part in the transmission of this disease.

Rat bite fever, a peculiar disease found in many parts of the world and especially in Japan is caused by the bites of rats. This, a specific infection and caused by a spirochete, is not to be confused with other secondary infections that may set in after bites by rats occur.

It is possible that the Ascaris lumbricoides, probably the most common animal parasite of man and found especially in children, might be disseminated indirectly through the rat which may harbor Ascaris eggs. Species of dwarf tapeworms and probably other worms commonly found in rats may find their way through the feces into foodstuffs which, when taken into the human system, may cause disease. Evidence is also accumulating showing that animal and vegetable parasites commonly observed in man are also capable of living in mice and rats. The rat absorbs and becomes the host of most all kind of organisms in its wanderings in garbage, dirt, filth, and later on foodstuffs to be consumed by man and animal. It is possible to find all types of bacteria and even animal parasites on or in the body of the rat. It may be that in the near future it will be found that the rat is the direct or indirect cause of many of the

disease conditions in man, the source of which has not as yet been clearly established.

METHODS FOR THE EXTERMINATION OF RATS

Even though man has waged ruthless warfare against this pest for centuries and human ingenuity has been taxed to the utmost to eradicate it, rats are still with us and their numbers and destructiveness have only been slightly diminished or decreased. Preventive measures perhaps are more important than curative measures if any marked success in exterminating the rat is to be achieved. Not only are preventive measures more effective, but the results are more enduring and the expenditures are not as great. The first and most important thing to remember is that *less food means fewer rats,* and *no food means no rats.* Garbage and refuse should be placed at all times in tightly covered metal containers. These should be emptied at frequent intervals and the contents should be properly disposed. Foods for man or animal in the home, store or market place should be kept in closed containers. Bins containing food found in public markets, food and provision shops, stables, feed stores, left open, are the gathering place of innumerable numbers of rats. To aid markedly in reducing the numbers of rats, they must be cut off of their food supply. Food should not be left lying around dog kennels, etc. Even pig pens should be kept more sanitary than one finds most of them and rats can be excluded from these environments by proper screen-wire enclosures.

Dwellings and all buildings should be of rat-proof construction. Concrete cellars and foundations have proven so valuable in aiding in the elimination of the rat that an ordinance should be enacted and strictly enforced in all communities providing for such construction in building operations. Contractors and builders should not regard rat-proofing details as trivial and accordingly neglect to carry them out. Efficient rat-proofing properly installed is a good investment. Construction of rat-proof buildings will deprive rats of the places they would otherwise use as breeding grounds and for shelter.

The permanent exclusion of rats involves the depriving these pests of a home. Thus it is the duty of the architect and builder to see that the proper construction and repairs are undertaken. Concrete floors, especially in large buildings, should be employed wherever possible, being sure however that a good grade of concrete properly

mixed was employed. Arrangements in the filling in of space or installing proper guards should be made whereby double walls are shut off from rats employing these as shelters. Upon the completion of the rat-proof construction with hard brick or concrete foundation, the owner and tenant should care for the upkeep in the use of proper rat-proofing procedures. Holes in walls should be filled in with cement, plaster, etc. Wherever possible broken glass with cement should be employed to stop up holes in walls of cellars, etc. Openings around heater and other pipes should be closed with metal sheeting or other guards or filled in. Basement windows and doors level with the ground, ventilators, roof and other openings should be fitted with durable and strong screening. Drains should be covered with grating or screen wire. Temporary structures or buildings without rat-proof foundation walls should be elevated about two feet and fine wire screening should surround the supporting beams. Planking should be removed from yards, alleyways, etc. Loose material should not be kept on the premises unless it is elevated on racks several feet above the ground.

Depriving the rat of food necessitates the application of sanitary measures. Food in stores, market places, etc., should be kept in rat-proof rooms or buildings. All foods should be placed in covered containers. Garbage and waste should be deposited in tightly covered metallic receptacles. Avoid piles of rubbish, dumps, wood piles, etc. Barns, sheds, pens for fowls and animals should have concrete foundations and walls and fine-mesh netting or grating covering all openings from foundation to roof. If these structures are not fitted with materials that cannot be pierced by rats, they should be elevated from the ground.

Of the several means of conveyance, vessels, both cargo and passenger boats, harbor and maintain considerable numbers of rats. Modern rat-proof shipbuilding is reducing markedly the number of infested ships. Careful inspection, continual watching and proper guards when these vessels are in port have succeeded in preventing rats, coming from some distant land and probably infected with plague, from making their way inland and finding their way to their fellow rats. Even on the rope used, guards must be employed, as rope makes an easy gangway on ships. If our health authorities guarding the ports in our and other civilized countries were not as persistent in their efforts, the deadly plague would be spread far and wide. The appalling indifference of the average man to this problem

is really at times deplorable, for to him the danger of plague and even the considerable economic loss seems a far-off cry.

DESTRUCTION OF RATS

Measures as mentioned previously should be instituted for the permanent riddance of rats. But even with these safeguards many places become infested. There are at times when such procedures are not practicable so that with preventive measures there must be combined methods of destroying rats. These methods will vary depending upon the conditions under which they must be used. Remember that there is no panacea for the rat scourge. There is no easy and quick road to rat riddance. Continuous application employing both preventive and eradication methods is required to be assured that this pest has been banished.

NATURAL ENEMIES OF RATS

There are many natural enemies of rats which are probably the most valuable ally of man. If the gamekeeper would leave these alone and if the farmer would learn more about them, he would confine the killing of such valuable birds only to those actually caught preying upon poultry. The others, which are a potent natural aid, would be left to kill and reduce the numbers of rats and other undesirable rodents.

It is therefore apparent that one of the important steps to be taken (especially on farms and in rural districts in a war against the rat) is the protection of its natural enemies. Among the latter, owls and hawks are probably the most important. Owls come swooping down upon their prey without making any noise. There are only three species of hawks and owls that live to any extent on poultry and birds, while the other forty odd species subsist mainly on mice and young rats. The three important harmful species are the Cooper hawk (Accipiter cooperi), the sharp-shinned hawk (Accipiter velox), and the great-horned owl (Bubo virginianus). The first two named species destroy 90 per cent. of the poultry and birds for which owls and hawks are responsible.

The weasel (Putela vulgaris) and pine marten (Mustela martes) are other merciless enemies of the rat. The former is unfortunately confused with the stoat. The latter living on poultry, rabbits, etc., is mistaken for the weasel which is given credit for the crimes thus perpetrated on the farm. The common or true kestrel (Falco

tinnunculus) and the female ferret (a variety of the polecat) are also qualified as natural enemies of the rat. The mongoose (common India mongoose, Herpestes mungo) is occasionally recommended and was used in areas infested with rats. But the experience with this natural enemy to the rat in Jamaica proved that the remedy is sometimes worse than the disease. Introduced into Jamaica to clear the sugar cane fields of rats, this animal rendered commendable service in the beginning, but finally measures had to be taken for the extermination of the mongooses, as the latter soon tired of a rat menu and it began to destroy poultry and other animals.

There are many species of non-poisonous snakes that are of considerable value to the farmer if the latter would only let them alone. Snakes found in fields, around grain, about farms, congregate there so as to catch gophers, mice, rats and ground squirrels. They can even make their way into narrow holes and trap rodents in their subterranean abodes, and are therefore more effective natural enemies than the hawk and the fox, who have to wait for the appearance of the rodents above ground. If the foolish prejudice against harmless reptiles would not prevail, the latter if not destroyed, would kill many of the rodents and thus aid in preserving the profits of the agriculturist. It would be an easy matter for an intelligent farmer to learn merely the differences in gross appearance between harmless and poisonous snakes if the latter were known to be found in his vicinity, and then allow the former which are frequently common to go unmolested.

Members of the crow family, the ravens and rooks, feed upon voles and lemmings. There are of course animals which are also objectionable pests and which, feeding upon rats, keep down the increase of rats. The several varieties of foxes eat mice, lemmings, etc.

Of the two domestic animals, a good terrior and a good cat, if properly trained, are worth large sums of money and are almost indispensable. Small fox terrier dogs cannot be excelled as rat hunters and are to be preferred. Cats taken as a class are not of real value as ratters, for the majority of them have evidently found that in these civilized days man is always ready to pet them and wait upon them; and accordingly the blessings of a luxurious civilization is much more preferable to them than a battle with a fierce courageous rat. In wide, open spaces, there is also the objection that cats may

become wild again, becoming themselves fierce, terrifying and objectionable pests. But apart from this when confined in stores, warehouses, plants, etc., certain breeds of cats, the proletarian species, not the feline de luxe, can be made to be valuable in destroying rats and mice.

Along with the preventive measures of not allowing rat harborage, keeping premises free of rubbish, or the use of natural enemies on the farm or a dog or cat in homes, other methods must be employed to destroy rats and keep down the rat scourge. These are by the use of chemical poisons, deadly cultures of disease-producing bacteria, trapping and fumigation.

QUAINT METHODS FOR GETTING RID OF RATS

In days gone by one finds recorded many odd practices advocated as the desirable method to rid any environment of rats. The use of obnoxious odors is advised by many well meaning individuals. "Burning the hoof or horn of a mule," "singeing the hair of a rat over the fire and letting it loose," and similar foul-smelling remedies are advised to be placed in their haunts as a means of producing an odor which is so offensive to the rats that they usually leave the environment wherein these odors are found. One unfortunately is left to conclude that the smell is not offensive to humans. We also hear that placing tar, pitch, glue or similar material on cardboard, etc., in and around rat holes will eventually drive rats away, as the latter observe members of their own tribe stuck to the tar, etc. A method at one time in frequent use was to fry small pieces of cork or sponge in bacon and use this as a bait.

The expelling of rats by incantation was firmly believed by many inhabitants a few centuries ago. To be effectual, enchantment was to be employed. Thus we hear Ben Jonson say "Rhyme them to death as they would Irish rats," and Shakespeare makes Rosalind say in "As You Like It": "I was never so berhymed, since I was an Irish rat." There are many other quaint practices, including the sprinkling of soil from holy ground in infested areas or invoking some saint to drive the pests away. Most of these remedies even if they are found to be of some benefit (and usually they are valueless), would provide only a temporary cure. It is also not in the general interest of humanity to get rid of these pests in one place and perhaps drive them into another environment where they are apt to be more troublesome.

The art of rat catching is a long interesting story concerning an old, universal and an apparently profitable occupation. Time does not permit a detailed consideration of this tale.

POISONS

The necessity for having available a means of destroying rats more quickly, especially when present over a larger area, is apparent. An ideal rat poison is one which is effective in destroying rats, is cheap in price, and is one which will not menace the lives of domestic animals and human beings. In the light of our present knowledge one will find that the poisonous rat preparations if effective for rats are in most instances poisonous or dangerous to man and other animals. The other objections to the use of poisons unless a slow-acting poison is employed is that the rats which die are apt to find themselves in inaccessible places, where their decomposing bodies may cause obnoxious odors. In addition, different baits containing the poison and changed at frequent intervals must be employed, or in some instances prebaiting, or the use of unpoisoned baits followed by baits containing poison must be tried, as it is a known fact that rats display an exceedingly fine instinct and possess sufficient intelligence not to touch the same bait which killed one of their own numbers. In the case of the slow poisons, which are preferred to those acting quickly, claims are made that most animals other than rats usually vomit these when administered while rats apparently retain such chemicals. When dying slowly the rat is apt to seek a quiet out-of-the-way place, usually not within the confines of walls, etc., in which to die.

The poisons and chemicals used most frequently for killing rats and mice are arsenic, phosphorous, strychnine, thallium, barium carbonate, plaster of Paris, and powdered red squill. Different vapors and gases have been tried in fumigation techniques.

When using any of these poisons one must remember that with the exception of the last-named drug (red squill), they all should be used in inaccessible places where pets and children are not apt to reach them. Even with this precaution there is always the danger that rats may carry poison food about thus exposing the latter to the temptation of being eaten by children and pets. The proper vehicle (bait) for the poison is very important and should be selected with care as most frequently the kind of bait used is of greater importance than the poison chosen. The bait must be made inviting for the rats to eat

and the poison must be properly mixed with it. Care must be exercised in the distributing of baits.

BARIUM COMPOUNDS

Various compounds of barium have been used as toxic agents for the destruction of rats. Barium carbonate has been found as the most desirable of these barium compounds to employ, as it is tasteless, odorless, inexpensive and slow in its action. It is highly recommended in place of the other poisons which are more dangerous to cats, dogs, chickens and other animals.

Twenty per cent. of barium carbonate in bait will be found to be an efficient concentration. This means the proportion of one part of chemical to four parts of the selected food, being sure that the former is worked well into the latter. The food employed as the bait should be fresh and of good quality and may be: (1) Cereals, such as powdered bread, cake or biscuit, corn meal, oatmeal, or rice flour; (2) meats or fish, as Hamburg steak, liver, bacon, sausage, fish, sardines, or cheese. Bacon and toasted cheese are effective baits though cheese is preferred by mice, but is not relished as much by rats; (3) vegetables or fruits, as thin slices of mashed apples, melons, banana, boiled pumpkin, boiled carrot or sweet potato. After mixing well the one part of barium carbonate with four parts of any of the previously mentioned baits, water should be added to make the finished preparation of the consistency of mush. I have always added a pinch of saccharin or some sugar to sweeten this mixture. At times when this bait seems to have remained untouched by the rats the addition of a flavoring agent, as a few drops of vanilla, oil of anise or oil of caraway, to the mixture seems to make it more inviting. These scents attract rats and mice. A still better practice is to make several batches of bait and poison, employing a different food as the bait in each of the several batches. A variety of baits giving the rat a choice is more apt to be effective for the destruction of these pests. Frequently the best bait to employ is one made from the same food found in the infested area. Rats frequenting meat markets are best trapped by the use of meat baits; those found in provision and fruit stores are easily captured with vegetable and fruit baits, etc.

The bait prepared freshly should be distributed freely in the evening in places frequented by rats. One or two teaspoonfuls of the different prepared mixtures should be placed in small envelopes, sacks, opened pill boxes or ointment lids. A number of these pack-

ages should be distributed at the same time on the premises. It is best to have an excess than too little of the bait and poison. This may result in the killing of most of the rats at one operation. Otherwise, if an insufficient number of baits was employed at one time, the resulting death of a few rats will arouse the suspicion of the pests still unharmed, so that subsequent baiting may not prove successful.

Bait which has not been touched within twenty-four hours by rats should be destroyed, as decomposition usually sets in and such bait is not inviting to the rats. If baiting on two or three successive nights proves ineffective, it is best to wait one or two weeks before repeating treatment with poison baits. If the use of this technique does not prove successful, it is advisable to repeat the operation, using plain bait without poison, and employing a new composition in the bait itself. If this is taken freely, it is supplied again the next evening and after an interval of a day or two the same bait, but to which the barium carbonate or other poison has been added, is substituted.

RED SQUILL

Squill (Urginea maritima, also known as U. scilla) is a perennial plant growing wild in the countries along the Mediterranean Sea. There are two commercial varieties of squill—white squill which is marketed as dry, white scales used for making medicinal preparations, and red squill which until recently was obtainable only as the fresh bulb.

White squill is apparently non-poisonous to rats. The brown rat and related species are susceptible to red squill, while the latter in the bait commonly employed will not be eaten by most animals or if it is consumed, there is produced an almost immediate vomiting resulting in the removal of the poison. Rats do not vomit. They take red squill readily, retain the latter and cannot escape its effect. If the drug is active, it will kill these rodents. It is therefore safe to say that under normal conditions humans, cats, dogs, pigeons, chickens, cows, etc., are not susceptible to red squill in the concentration commonly employed to kill rats. Red squill, therefore more nearly approaches the ideal rat poison, being effective and a specific poison for rats, safe for other animals and its cost is comparatively cheap. Of importance to remember is the fact that the red squill powder or its preparations vary in their toxicity or poisonous effects. One must therefore be assured that the red squill which is being used has been tested and found to be active, otherwise if not potent it will

be ineffective. The purchase of red squill preparations as a raticide (to kill rats) should only be made from manufacturers who will guarantee the toxicity and effectiveness of their products.

Drying sliced red squill bulbs in an oven at 175 degrees F. will produce a powder which is markedly toxic. This should be mixed with any of the baits given under barium carbonate in the proportion of one part of red squill powder to nine parts of the cereal, meat, vegetable or fruit. Moisture is not necessary here and a dry squill bait will be found to be effective. Such a dry bait will not require frequent changing. If a liquid preparation of squill is used, a dry cereal should be used as the bait. Inasmuch as red squill may impart a slight taste to bait, the practice of using first plain bait may not only prove a more effective procedure, but may be necessary as rats will not immediately indulge heartily in any meal containing squill.

THALLIUM COMPOUNDS

Of the thallium compounds which are closely related to the lead group of metals, thallium sulphate is used to destroy rodents. It is tasteless, odorless, slow in its action, possesses an accumulative effect and it is more toxic than arsenic. When employed it is used with a suitable bait in a ½ per cent. concentration. This chemical is highly poisonous to humans and other animals. Inasmuch as it possesses no color, odor or taste, its presence is not revealed in bait containing it and accordingly it is unadvisable to advocate the general use of this chemical. In the hands of careful workers it is however exceptionally effective. Though somewhat more expensive than the other drugs or chemicals employed as rat poisons, it is more effective and therefore cheaper than other substances in the long run.

STRYCHNINE

Though strychnine is an effective poison for rats, it is not regarded with much favor, as most rats refuse to eat bait containing this drug due to the bitter taste of the latter. When effective it may even cause instant death, a circumstance which may make it unadvisable to use this drug in inhabited dwellings, as the rats will die beneath floorings, etc., and their bodies will decay, causing foul odors. When employed, strychnine sulphate is used in a 1 per cent. concentration. Mice are more susceptible to strychnine than rats, so that this drug is a valuable destructive agent to employ for ridding an environment of mice.

ARSENIC Arsenic, because of its cheap cost and mainly in the form of arsenic trioxide, is widely used as a rat poison with bait in 5 per cent. concentrations. It may be found to be variable in its effect upon rats unless employed by one who is careful in the selection of the bait. Being odorless, tasteless, colorless and poisonous to humans and animals, precautionary measures are to be employed when using this chemical.

PHOSPHORUS This is another deadly poison for rats and when employed is used with a bait in 2 per cent. concentrations. The danger of this chemical is however that it is inflammable and a fire hazard.

OTHER POISONS Other chemicals and drugs as cantharides, etc., have been advocated and employed as rat poisons. Most of them are either ineffective or due to other hazardous properties are not to be recommended. I might however mention that I have used with effective results plaster of Paris (calcium sulphate) employing one part of the chemical to one or two parts of flavored preferably dry bait.

In areas where bubonic plague is prevalent, chloropicrin has been suggested as a poison. It has the advantage of killing the fleas on the rats even before the latter perish. This is of great importance, for if the infected fleas survive, the danger of plague still remains even though the rats die later on. Chloropicrin will drive rats from any environment. A solution of this chemical in trichlorethylene may be sprayed in burrows, under floorings, between walls, etc.

TRAPPING Trapping rats is the only procedure to employ when other methods are not advisable or cannot be used. This method requiring greater skill and more labor is very effective if careful attention is given to details.

Traps are constructed selling for a few pennies a piece to the elaborate and ingenious cage traps selling for several dollars. Complicated contrivances and fancy traps, though useful, may be best replaced by the primitive and simple snap trap known also as the "guillotine" or "spring." Generally speaking, the best trap is useless unless baited properly with a satisfactory bait and then placed at night in areas frequented by the rats and in such a position that the rodent in following its natural course will pass directly over the

trigger. Rats frequently follow the same track night after night. Strength, durability, and a sensitive and preferably large trigger should influence the selection of a trap rather than its appearance or cost.

Any bait mentioned previously as the vehicle for poisons may be used as the bait when trapping, but satisfactory results will only be obtained providing the bait is *fresh*. A variety of baits, changed daily, may also yield better results. Fresh meat, cake, bread, doughnuts, fish, fruit or vegetable over which there is sprinkled some powdered cereal, are attractive baits. The powdered cereal may be sprinkled lightly over the entire trap, thus hiding the latter. If a cage trap is used, this may be covered lightly with straw, dead leaves, a piece of carpet or an empty box. Such camouflage may be necessary to outwit rats, for they are cunning creatures quick to discover the danger that threatens from such devices, unless the latter are hidden. Rats have a peculiarity of running into a hole. A sufficient number of traps should be employed during trapping. Don't use one trap when one-half dozen are needed. It is best to introduce an excess number of these contrivances in an infested area than to have an insufficient quantity of them, as trapping is most successful when the campaign is planned well and completed within a short period of time.

The barrel trap, the pit trap and different home-made devices have been employed for catching rats. Foodstuffs should be placed at all times in covered containers and not within reach of rats and especially so when trapping. Traps possessing a foul odor should be boiled and those in which the metal parts have rusted or the odor still persists after boiling should be discarded. Human perspiration, rat blood and iron rust give odors detected by an alert rat. Expert trappers frequently wear rubber gloves when preparing traps, thus avoiding the possibility of the latter being soiled with human perspiration. Traps should be examined before use to be sure that the springs are not stiff. They should be examined daily to change the bait, which is usually necessary, or to be adjusted, for traps may have sprung without making a catch. It may be advisable to fasten traps by means of a cord to the wall or some heavy object. Unless careful attention is given to the details as mentioned here, but little success will be achieved in any campaign of trapping rats. Those who become proficient in rat trapping usually have become familiar with the habits and appetites of these pests they plan to capture. They

use clean traps, prepare them with a satisfactory fresh bait, and place sufficient numbers of them in rat runs or in their hiding places.

Another mechanical contrivance is one which is constructed similar to the simple traps and which when even momentarily touched by the pest connects with an electric current, resulting in the electrocution of the rodent. This is an effective and humane method of reducing the numbers of rats, but can only be employed where pets, children and others are not subjected to the danger of the electric current. However, a technique depending upon the use of electricity has been used in continental European countries. Electric wires were laid in sewers where rats are in abundance. Tempting delicacies and baits were placed on different places along these wires. As the rat rests a paw or any other part of its body upon the wire with the intention of partaking of the food, it is electrocuted.

FUMIGATION AND DETERRANTS

Various agents have been employed for the generation of gases, fumes or vapors which are effective for the killing of rats in burrows or other places harboring these pests. Fumigation in many places is not always possible, but where this method can be used and the gas can be confined for a designated period of time, such procedure is the most practicable in getting rid of rats and other pests.

The most efficient gas for destroying rats in areas where these fumes can be confined is hydrocyanic acid gas. Calcium cyanide dust may be employed effectively by forcing it into rat burrows, in fields, under floors and lumber piles, garbage, manure piles, etc., or other harbors by means of a dusting pump or bellows. In the presence of the moisture in the air, calcium cyanide gives off hydrocyanic acid. Hydrocyanic acid gas is deadly to humans. This method of fumigation therefore should only be employed when other methods have failed or where other forms of animal and human life are not present; and then it should be intrusted only to those experienced in handling this fumigant. Vessels, especially those with cargo-laden holds, are best rid of rats by proper cyanide gas fumigation.

Burning sulphur produces sulphur dioxide gas. Sulphur fumigation is effective for destroying rats providing a sufficient amount of sulphur is used and a prolonged exposure is practiced. At least three and one-half pounds of sulphur should be employed for each 1000 cubic feet of space and the gas is to be confined for twenty-four hours. A longer length of time for exposure and the use of more sulphur is necessary if the environment is laden with a large amount

of material. The following technique is generally employed: Before generating the gas, the inclosure to be treated is made as tight as possible. Machinery and metal furnishings are usually protected by coating them with a thin layer of vaseline. A number of broad, shallow iron pots (about one to two feet in diameter with sides from three to six inches high) are filled to a depth of not more than two inches with sulphur (powdered or coarsely broken stick) and the latter is sloped toward the center so as to form a crater. Into the latter is placed a piece of cotton moistened with alcohol or gasoline, which is lighted. A hot coal or red hot bolt may also be used to ignite the sulphur. The pots of sulphur are placed on stone or sand or on bricks extending out of water contained in a basin or tub. The pots should not touch the water as moisture would be liberated and sulphur dioxide in the presence of moisture will bleach material in the environment which is being treated. The sulphur should be evenly distributed in several pots and after the operator has assured himself that the sulphur in all the pots is ignited, the room is closed and the gas is given an exposure for the desired length of time. Of the many fumigants, sulphur dioxide is the least harmful to humans. Due to its slow action and the fact that it may bleach material if there is much humidity present, the use of this gas has not been popularized in this country.

By means of special devices and apparatus, the gas coming from the flue (flue gas) (containing about 1 per cent. carbon monoxide and 10 per cent. carbon dioxide) has been used especially on vessels to destroy rats. This gas is odorless, non-explosive, inflammable, and because it is very poisonous, it has not been employed extensively.

Similar to the flue gas, exhaust gases from gasoline engines, as in tractors, automobiles, etc., have been used to kill rats in their burrows and in tight enclosures, as beneath floors, etc. The exhaust is guided into the rat burrow by means of a rubber hose. After the carburetor is adjusted to obtain a rich mixture, the engine is allowed to run for at least one-quarter of an hour. The hose is removed and the hole is sealed with strips of metal or wood, or if the burrow is in the ground, damp soil is used to clog up the hole, thus confining the gas.

Carbon disulphide is also effective in destroying rats in their burrows and may be used in fields, in holes in cellars, barns or similar places. Cotton or rags are moistened with two or three tablespoonfuls of this liquid. These are pushed into each burrow entrance, and the

latter is sealed with moist earth or by other means. Care should be taken when handling this liquid, as it is inflammable and even explosive.

Some of the previous mentioned gases will act at least as deterrents (drive the pests away rather than destroy them). Of marked value as a deterrent is the liberal use of flake naphthalene (so called "flake camphor"). The latter, if distributed freely, will keep rats away. On account of the odor it imparts, naphthalene can only be used in places where this is not objectionable or unless the material to which its odor adheres can be thoroughly aired before use. Powdered sulphur, capsicum, pepper, oils of wintergreen and peppermint, carbolic acid and cresol, gasoline and kerosene and other wood and coal tar derivatives are substances objectionable to rats and can be sprinkled or blown in with a bellows or blown or sprayed in burrows, between floorings, walls and other rat harbors.

THE USE OF BACTERIAL PREPARATIONS

Bacteria have been employed in the destruction of rats.

Disease-producing bacteria produce their own respective defined diseases and what is more many of them display additional specialization in that when causing disease the latter is produced by them in certain animals and not in others. In other words, the organism may produce disease in a dog but not in the rat, cat or human being or vice versa. Many investigators have experimented with the view to the discovery of an organism which will be fatal only to rats and allied rodents, but harmless to other animals. Such a bacterium, supplied in a suitable bait, would be easy to use, cheap in cost, and would be capable of eventually producing a fatal disease in, and due to the contagiousness of this disease, subsequent death to the entire community of rats present within any given area. With this thought in mind, we have investigators introducing different organisms for which they claim special consideration. Issatschenko's bacillus has been used extensively in Russia. In 1900 Danyzs described his bacillus, originally isolated from a spontaneous epidemic among harvest mice. Cultures of this organism were sold under the name of Danyzs virus. In 1903 Neumann discovered a bacillus which he claimed to be more powerful than any of the others which had been introduced. This supplied in a suitable bait and sold under the name of "Ratin" was used extensively throughout Sweden, Scandinavia, Germany and other countries.

Other culture supplied in different baits have been sold under varied names, as "Raticide," "Azra," "Pasteur Virus," etc.

Cultures or viruses in the hands of professional rat exterminators may prove more effective as these are usually fresh or of recent origin. Preparations sold to the laity are however several months old when they reach the consumer, so that one finds the organisms may have lost their power of producing a highly fatal disease in rodents.

Without going into detail concerning the disease produced by the bacterial cultures for the destruction of rats, and the contagiousness of the disease from the infected rat to other rats, it may be said that the cultures introduced to date are of little practical value in the hands of the laity for the extermination of rats. Not only have the diseases produced by these cultures in the rats been only slightly contagious, so that there has been very little spread of the disease from rat to rat, but what is of grave danger to humans is that the organisms themselves may not be as harmless to man as was at first believed to be the case. Most of these organisms in the various rat viruses are closely related biologically to the same group of bacteria producing food poisoning in man, as to make it a difficult task to distinguish the former from the latter. It of course may be impossible to definitely trace cases of human food poison to rat viruses or cultures. But with this in mind and their practically ineffectiveness in the destruction of large numbers of rats, the use of these viruses are not recommended.

COMMUNITY ORGANIZATION

Fighting the rat should not be looked upon as sectional crusades against an undesirable pest. Rats are one of man's chief rivals for the possession of the earth. They are just as damaging today as they were centuries ago and from an economical standpoint we sustain greater losses today due to the rat's ravages than during any time since the beginning of civilization. To rid environments of rats requires not only individual effort but an organized campaign with united action by the community at large is frequently essential to insure permanent relief from rat infestation.

Anti-rat legislation is necessary in addition to the proper public spirit in co-operation. Such legislation includes proper rat-proof construction, satisfactory handling, keeping and disposal of waste, garbage, etc. In some foreign countries anti-rat legislation goes even

further, as is evidenced in the Danish Rat Law of 1908, passed due to the efforts of Zuschlag and the "Danish Association for the Extermination of Rats." The Danish Rat Law provides for a combination of effort between the state, local municipalities and the Danish Society for the Extermination of Rats on the one hand and the public on the other. The former supply and provide means and methods for getting rid of rats and make arrangements for the reception and disposal of dead rats for which premiums are paid to those handing them in.

TREES

By Marin S. Dunn, Ph. D.

A. Forests and Forestry

THERE WAS a time, not so long ago, when the land comprising the state we know as Pennsylvania was far more heavily wooded than it is today. A vast forest, rich in kinds and numbers of its trees and abounding in wild life, covered much of the land. Because of its favorable location and climate, Pennsylvania was the common meeting place of tree species from the north, the south and the Mississippi basin. Giants, heavy with age, whose lofty heads had defied storm and cold for hundreds of years, were common. But, upon the arrival of the white man, conditions began to change. With wood so plentiful, little heed was taken to protect the forests, and grove after grove fell before the axe in order to clear land for homes and farms. Fires, due to intent or carelessness, played their parts in ruthlessly wiping out vast acres of valuable timber, leaving desolation and death in their wake. Lumbermen, destroying the wooden treasure chest by unregulated cutting, have completed the picture. With the passing of time, the inroads of fire and man have reduced the original dense forest to relatively small, open woodlands. Forest giants are still to be found, but not in great numbers.

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It must not be thought, however, that Pennsylvania is the only state where the conditions described above have occurred. The same tendencies have been in operation wherever many valuable trees were found. Economic pressure and carelessness, owing to overabundance of supply, with no thought of the future, are largely responsible for the despoiling of forests. A recent article appeared in the *New York Herald Tribune,* under the name of Nelson Courtlandt Brown, Acting Dean of the New York State College of Forestry, which brings out the point that, although New York was at one time the great pulp and paper-producing state of the nation, there is said today to be only ten companies which have a supply of pulp sufficient to last ten

years and only one company that has a twenty-year supply, and that, as a consequence, many paper and pulp companies are moving their mills to Canada.

But there is a hopeful side to the picture. Certain people of high ideals and standards, looking at the problem of forest conservation with a critical eye, and realizing where wood wastefulness will lead us, are doing much toward developing a constructive program in the treatment of our woodlands. This program consists, among other things, in awakening our people through educational channels to the value of the forest; the training of spirited young men in established schools of recognized worth to care scientifically for the present forests; fighting fire, fungus and insect, etc.; in acquiring and setting aside new forest land to be protected in the proper way; and by judicious tree planting.

Generations ago, 1681, in Pennsylvania, wise old William Penn, realizing the value of the forest, ordered the people to set aside one acre of trees for every five acres cleared. Nearly two centuries elapsed before any constructive work in forestry was done. In 1886 the Pennsylvania Forestry Association was founded and in 1895 a Division of Forestry was created in the Department of Agriculture, which later, in 1901, became the Department of Forestry. In 1903 the State Forest Academy at Mont Alto was established in order to prepare scientifically trained and equipped foresters to serve the state. To quote from "Pennsylvania Trees," (3), page 20, "The school aims to give the students a thorough and practical training in the surveying and mapping of forest areas; the growing of trees and their proper management from planting, through thinning to final logging and sawing; the protection of forests from fire, insects, fungi and trespass; the building and improvement of forest roads, trails, fire-lines, telephone-lines and fire towers; the estimation of timber and the calculation of its growth, value and financial returns; the directing of labor; the keeping of records and accounts; and some knowledge of business and forest law."

The graduates of this academy go out to all parts of the state teaching the importance of forestry and they also act as executives for the more than fifty state forests. These Pennsylvania state forests comprise 1,133,051 acres acquired 1898-1927, and 453,500 acres acquired 1927-1931. More than 36,000,000 trees have been planted in the State Forest of Pennsylvania which now equal in area a strip nine miles wide across the entire state. New York is also intensively

planting trees and, in the article by Nelson C. Brown referred to, the statement is made that 25,000,000 little forest trees were set out in 1929. "But even at this rate it would require about 200 years to put to work all the idle and abandoned lands that are unfit for agriculture and unprofitable if devoted to anything but trees. This is sadly but indeed true for the great Empire State. It is also true in almost comparable manner in New England, the lake states of Michigan, Wisconsin and Minnesota, throughout the southern states, and even in many parts of the rich agricultural states of the middle west."

Forests vary in different localities depending upon the environmental factors involved. In some woodlands, a single species of tree makes up 90 per cent. or over of the entire growth. This is called a pure stand. Pure stands in Pennsylvania are rare and, when found, are often conifers (cone-bearing trees). The opposite of the pure stand is the mixed one where two or more species enter into the composition of the woods, no one species making up 90 per cent. of the total. To the forester, pure stands may be established more easily and cheaply, but they lack some of the outstanding advantages of mixed stands, such as the ability to meet changing market demands and the full utilization of the foods in the soil.

A tree, like every other living thing, may enjoy a normal span of life and, in a forest, we may find all stages from young seedlings still in their babyhood to aged monarchs that are nearly dead. (The oldest tree in the world is said to be the giant cypress near Oaxaca in Mexico. Although not as high as the big redwoods of California, nor the eucalyptus of Australia, it has a circumference well over 100 feet near its base and is probably 5000 years old.)

Age, however, does not alone take its toll of trees, but many other influences are at work to bring about destruction and death.

Branches may be broken and entire trees uprooted by wind. Frost is often responsible for injuring the soft parts, such as buds and shoots, and it even causes the splitting of branches and fruits. Snow and ice, by their weight, are guilty of breaking branches; hail, especially in spring, may injure flowers and young fruits. In fact, heat and cold, if sufficiently pronounced, will destroy life. Lightning is one of the causes for the starting of forest fires which burn over large areas of land.

Grazing sheep and cattle play their part by eating the available plant food found within their reach. Insects are a serious menace to our forests and each species of tree has its particular enemies.

Some insects (scale insects, plant lice, etc.) belong to the type that have sucking mouth parts by which they are able to pierce fruits, young buds and twigs, and suck out the plant juices. Others have jaws adapted for chewing and destroy the actual plant body. The borers belong to the latter group and, as their name indicates, they are found in tunnels of their own construction in various parts of plants. Bailey (1) says, "The two apple-tree borers, the round-headed and the flat-headed species, and the peach-tree borer doubtless cause the death of as many apple and peach trees in America as all other enemies combined." Boring insects cannot be reached by spraying and they must actually be dug out, often a very difficult undertaking.

Fungi, including the bacteria, is a group of plants, some of whose members are extremely harmful to trees. Fungi are colorless plants which reproduce by little cells known as spores. These spores are extremely small and light and are carried by various natural agencies, such as the wind. If the spores come in contact with breaks or wounds in the surface of living plants and if there be favorable conditions present, such as proper moisture and heat, the spore cells may sprout into threads which, in turn, derive nourishment from the host plant and grow into or along the surface of the host. In many cases a conspicuous fungal growth, which may take various forms, depending upon the species of fungus, above the surface of the tree is associated with a great interwoven mass of fungal threads which has penetrated the tissues within the tree. As the growth of the fungus continues, more and more of the tree is damaged and, as a result, the tree may be seriously injured or even killed. Toadstools, mildews, rusts, blights and rots are types of fungi which are commonly known to almost everyone.

Man, himself, however, is the greatest living destroyer of trees. From the time of the pioneer, who was forced to wage his life-or-death battle with the forest, to the period where trees were ruthlessly cut with no heed for the future, man has been the great enemy of the forest. The responsibility lays at his door for most of the disastrous forest fires—fires which burn every year in Pennsylvania alone thousands of acres of timber. Old trees and young are not spared, but are left as charred wrecks after the passage of the fire. Statistics show that 2456 forest fires occurred in Pennsylvania during 1928. These burned over 110,872 acres, creating a damage of $360,000. A carelessly thrown cigarette butt, the lighted stub of a match, or a smould-

ering campfire may leave as a monument to the ignorance or indifference of man, himself, the ruins of a hundred acres or more of good timber and much animal life.

Strange as it may seem to many, many forest fires occur in April and May, and these produce a great deal of damage, since they burn plants at the time of most rapid cell division. It is said that the trees of Pennsylvania make 90 per cent. of their height growth during about forty days in spring. The spring sun dries the leaves on the forest floor before the season's new leaves are produced on the trees above, with the result that there is sufficient fuel in a readily burnable condition to be set off at the slightest cause. Another period of maximum fires occurs in autumn when the dead leaves cover the surface, and when they are not yet covered by the winter's snow. Young trees and young parts of trees are most apt to suffer from fire since here the cambium or growing layer is not heavily protected. As trees grow older, their mark becomes thicker and heavier with the result that they are better able to withstand exposure to fire. However, they are not always exempt from death because of their size. It is also known that some trees, such as conifers, the beech, etc., because of their nature, are injured far more than others.

Three general types of forest fires are recognized: (1) ground fires which burn into and through combustible soil, (2) surface fires which harm anything burnable in their path along the surface of the ground, (3) crown fires, fortunately few in Pennsylvania, which attack the upper portions of trees. If the wind is too strong, a fire which is normally a surface fire may become a crown fire. Trees having pitchy material may become living torches and quickly carry fire from below into their crowns.

In conclusion, forest fires produce damage only, and it is the duty of everyone to protect the forest against any act of carelessness which might endanger property and life. While in the woods or near burnable timber, be certain that any fire which should be out is entirely out. Beware, also, of the lighted cigar or cigarette stub which may be thrown from automobiles while driving on roads passing through woodland areas. It is advisable for every machine to have its own ash tray so available that it is accessible to all occupants of the car.

From the foregoing paragraphs, we see that nature, in order to hold her own, always faces the problem of making up the losses occasioned by the various agencies just discussed. Not only must

she repair damages to old forests, but new forests must be gradually built. One of her principal methods is by innumerable seeds, each of which contains a tiny embryo plant of exactly the same type as the parents that produced it. Seeds, themselves, may be developed inside of containers known as fruits. Seeds ripen at different times of the year, depending upon their kind, and may be carried from the parent plant in a number of ways. Often the fruits containing the seed show striking structural adaptations to their method of dispersal. For example, wind-borne fruits of the willow and aspen are equipped with hair, while those of the American elm, ash and maple have wing-like expansions. Streams may carry certain fruits and seeds for varying distances. This is particularly true of those which are naturally built for floating, such as the American hop hornbeam with its bladderlike container. Some seeds, contained within succulent fruits, are swallowed by birds as they eat the juicy part. Such swallowed seeds may pass through the bird's intestines unharmed and come to fall in regions at a distance from the place of eating. This may be the fate of the seeds of the hollies. Certain seeds cling to the outside of the bodies of the forest inhabitants to which they may come in contact and may be carried far away before they are brushed off. Finally, in the case of those species growing on cliff sides, gravity may play its part.

Whatever the method of scattering, if the living seed finds itself in a location having suitable conditions, its embryo may develop into a new plant, and hence it is that we find the forest floor dotted with seedling trees in various stages of development. Each one, providing disaster does not occur, will become in time an adult forest tree. However, do not imagine for a minute that all the seeds formed by a tree will grow into a new plant. As Rogers (5) so aptly puts it, "Thousands of tree seeds are sown where but tens may hope to germinate and grow. Some seeds (e. g., willow) must germinate at once or they lose their vitality and die. Most of these cannot start unless they fall in very moist soil. So each has its peculiar limitations, and these keep the number of seedlings down." The willow, however, is able to surmount its seed difficulty by the ease with which branches are separated from the parent plant and falling in the water beside which the willow is growing, float off until a place is reached where they come into contact with land and may take root.

Still another way that natural regeneration may take place is by means of shoots and suckers. Many readers of this paper probably have noticed, again and again while walking through our woodlands, that certain tree stumps are surrounded by a ring of young sprouts. These shoots, fed by the root system of the parent plant, are rapid-growing. Oak, chestnut and various other deciduous (dropping their leaves as winter approaches) trees have this habit while it is limited to the redwood and pitch pine among conifers. Suckers are the growths which spring up from the roots or lower part of the stems of certain trees even though the parent tree be still standing. Go to your window, and if you have Lombardy poplars in your yard, you may notice this condition. The word "coppice" is applied to both shoots from the trunk stump and suckers springing from the roots And coppice represents a quick method nature uses to repopulate her forests with trees.

Natural regeneration takes time and often is very wasteful, and so man has attempted to assist nature by guiding her and improving upon her methods. First, in this artificial method of regeneration, seeds are collected from suitable trees and are properly stored in protected places or planted at once. If they are sown immediately, two courses present themselves; either sowing them in the forest in locations where they are expected to develop into mature trees, or that of placing them in especially established nurseries at first. In Pennsylvania, the nursing seed beds are generally about twenty-five feet long and four feet wide, and after germination, the young seedlings break through the ground into the light of day. If too many seedlings develop in a single bed, some of them, as time goes on, are transferred to another location. This transplanting is really a good thing because the seedling plants that survive it are healthier and stronger. When the time arrives (which varies with different species —ash, one year; white pine, two or three years, etc.), the seedlings are taken up and replanted in the forest where it is intended that they shall grow. Trees, located in this way, are usually placed four by four or five by five feet from each other, resulting in from 1700 to over 2700 trees necessary per acre.

Another method is to take seedlings, which are germinating in the forest, and transfer them directly to the location where they will be used, and in this way to shape the forest to its own interests.

From the view of the lumber merchant, trees grown in open stands will produce lateral branches near the ground and, consequently, since the lumber obtained from the trunks of such trees is full of knots (each knot representing the influence of a side branch), the result is an inferior grade of wood. On the other hand, when the trees are grown comparatively near each other, lateral branches will appear higher up and the timber will yield relatively fewer knots. The expert forester, in developing a timber forest, will aim particularly to increase the yield of wood and make it more valuable than if left to nature alone.

The experienced forester will fit his methods to the problem at hand. In some cases he may use artificial regeneration, while in others he may allow natural regeneration to play its part and then fill in the gaps or vacant spaces artificially. The artificial method has been used to cover open areas. In Pennsylvania Trees (3) the statement is made, "Many of the forests which were established artificially are now reaching maturity. Disadvantages of this method are becoming more evident and the foresters are gradually substituting the natural method for the artificial." Let it be understood, however, that one method differs from the other, mainly by how much man assists nature and tries to shape her efforts.

B. Transplanting Trees

We have spoken before of transplanting but only in connection with seedlings. It is now time to say a few words about transplanting larger trees. To begin, a safe rule to follow as nearly as possible is that of not letting the tree know it has been moved. In other words, attempt to keep conditions during and after transplanting as nearly as possible like those to which the tree is accustomed. This is best done in early spring before the warming sun has awakened it from its long winter sleep.

If the tree under consideration possesses fibrous roots, dig carefully about it in a circle about as wide as the tree's crown, leaving the sod in place. Gradually work under the tree until it is possible to get it separated together with much of its root system still wrapped in its earthen ball. If there is a long fleshy tap root, as in the case of the white oak, this may be cut off at a little distance below the surface some months before the actual transplanting in order to give a chance for a more superficial root system to develop. In general,

if the root system is dense and shallow, as in the case of elms and maples, the chances of successful transplanting are better.

The roots of some trees, black walnut, horse-chestnut, beech, etc., are in intimate relationship with certain soil fungi. These fungal threads form a mantle (mycorrhiza) over the surface of the roots and may even penetrate the root cells and thus may assist the roots in absorbing nutrient materials from the soil. The ground under certain trees for example, is completely penetrated by these threads and if you transplant a tree of this kind to your garden, be sure to take some of the original soil in order that the fungal threads which the tree needs may not be missing. If your garden soil does not contain these threads, your tree may die.

In the last few years commercial concerns have found it possible to transplant large trees, using specially built equipment. In fact, it is now possible, if you possess inclination and money enough to convey living forest giants to your very door. Recently one reads in a New York paper of a number of large trees so conveyed and replanted. The list, as given, includes: one elm, forty-eight inches in diameter and 100 feet high; four elms, forty-two inches in diameter, ninety to 100 feet high; twenty elms and white pines, twenty-six to forty-two inches in diameter; 300 elms, white pines, maples and concolor fir, twelve to twenty-four incres in diameter. No longer must one wait through the years for one's trees to grow, but one may in a few weeks transform a bare house and lot into a shady old estate.

Julia Ellen Rogers in "Trees" (5), gives the following directions in replanting the young tree which has been taken from its woodland home. Dig the hole larger than the tree requires. Place a layer of especially rich soil on the bottom. Do not allow exposed roots to dry and the root hairs to shrivel. After trimming broken roots, place the plant on this rich bed in such a way that its roots are not cramped by being pushed together, but are placed naturally. Do not bury the tree too deeply, but try in every way possible to duplicate the original condition. Place good dirt around and between the roots. Add water if the tree is not dormant and then after it has soaked away, finish filling the hole with soil so that the tree may stand firmly. It pays to prune the top and thus shape it. In doing so, you not only form a fine top, but you may prevent the loss of too much water from the leaves before the root system is fully established and able to absorb sufficient water for its needs. As soon as you note signs of the awakening, thorough watering is needed.

C. Pruning Trees

And now, since we have mentioned pruning, it is a good place to briefly discuss a few general principles involved in this act which may be defined as the cutting out of parts for the improvement of the parts that remain. In this process, dead, diseased or injured parts are removed. Generally speaking, plants are best pruned in early spring, although dead parts may be removed at any time. Ornamental trees grown for their flowers, if early blooming, may be pruned after the blooming of the flowers. It all depends upon the purpose of the owner and the kind of tree as to the way in which pruning is carried out. We should hold in mind the picture of trees with their roots firmly fixed in the ground absorbing water and mineral salts from the soil and passing them upwards through their trunk to their leaves. If the desire is to lessen top growth, the roots may be pruned. On the other hand, if the terminal buds are removed, increased activity on the part of those buds which remain leads to a thickly branched and spreading plant. This, in turn, leads to the production of flowers and fruits, rather than wood. Hence, if the tree is a fruit tree, pruning includes the removal of the growing regions at the top and, later, it may also embrace a thinning of the remaining branches so that the energy which goes into the formation of the fruit will not be expended in a great number of mediocre clusters but shall be concentrated in the very finest producible.

In the case of forest trees, where the purpose is to raise wood, the terminal buds are not removed but the plants are induced to grow clean and straight with as much wood as possible. In many cases the branches near the ground die and are removed by nature in her own way. If, however, this does not occur, it may be necessary to clear them.

In the case of evergreen trees, the terminal bud of the main trunk should never be cut, although it may be necessary, at times, in order to shape the tree, to remove the terminal buds of side branches in order that the remaining bud system develops more fully and thus produces a compact head of foliage.

Tender shoots may be pinched back by hand or by the use of a sharp pruning knife. If, however, the tree is older, and its limbs so thick that the use of special pruning implements is rendered difficult, it may be necessary to use a saw. Always cut the limb off at its base as nearly as possible on a level with the branch from which

it arises. Never leave a long stump or stub behind to decay. A hatchet or axe would cause an uneven torn surface or possibly a long split, through which infection may more easily occur. Where the stub is long, the dead wood becoming wet through rain, affords ideal conditions for the entrance and germination of fungal spores. The result is decay, which may eat through the stub into the vital parts of the tree. In the process of healing, new tissue is formed at the sides of the cut branch and closes in over the wound. The longer the stub, the more difficult this process.

After the cutting has been accomplished, it is necessary to sterilize and waterproof the wound. The purpose of this is to kill fungal spores lodged upon the wound and to prevent the entrance of water. To some extent it also guards against boring insects. Corrosive sublimate of proper strength is one of the best antiseptics for this purpose, while a paint composed of linseed oil and white lead, or liquid asphaltum, may be used for waterproofing.

D. The Tree

Let us pause at this point in order that we may get a better idea of the organization of a tree. Take some tree—almost any tree will do—and look at it more closely. (Fig. 2.)

It is composed of millions upon millions of tiny cells of various sizes and shapes. Cells of common origin, structure and function are grouped to form tissues and these tissues in turn make up the fundamental plant organs—root, stems, leaf, flower, fruit and seed. (Fig. 2.)

The roots are embedded in the soil and have for functions anchorage, storage and absorption of water and mineral salts found in the ground. This crude sap is passed upward through certain channels known as fibrovascular bundles or just bundles (Figs. 2, 7), into the stem or tree trunk and eventually reaches, by smaller and smaller side branches, the flat expanses called leaves. The leaves have the power, by virtue of their green substance—chlorophyll—of utilizing the vast energy of sunlight to build up complex food, such as starch, out of water which reaches them from the roots and from the carbon dioxide gas which enters them from the atmosphere. (Fig. 1.) Some of this elaborated food, thus made, is used as food for the cells that form it—the remainder, in the form of sugar, is passed out of the leaves through fibrovascular bundles to various

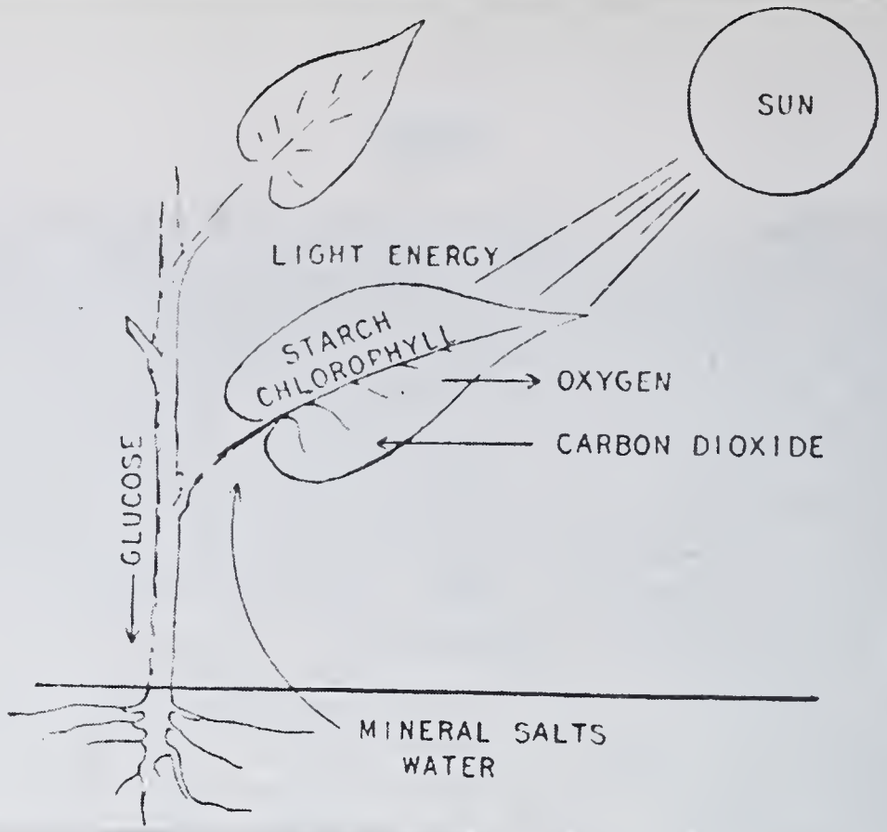

FIG. 1

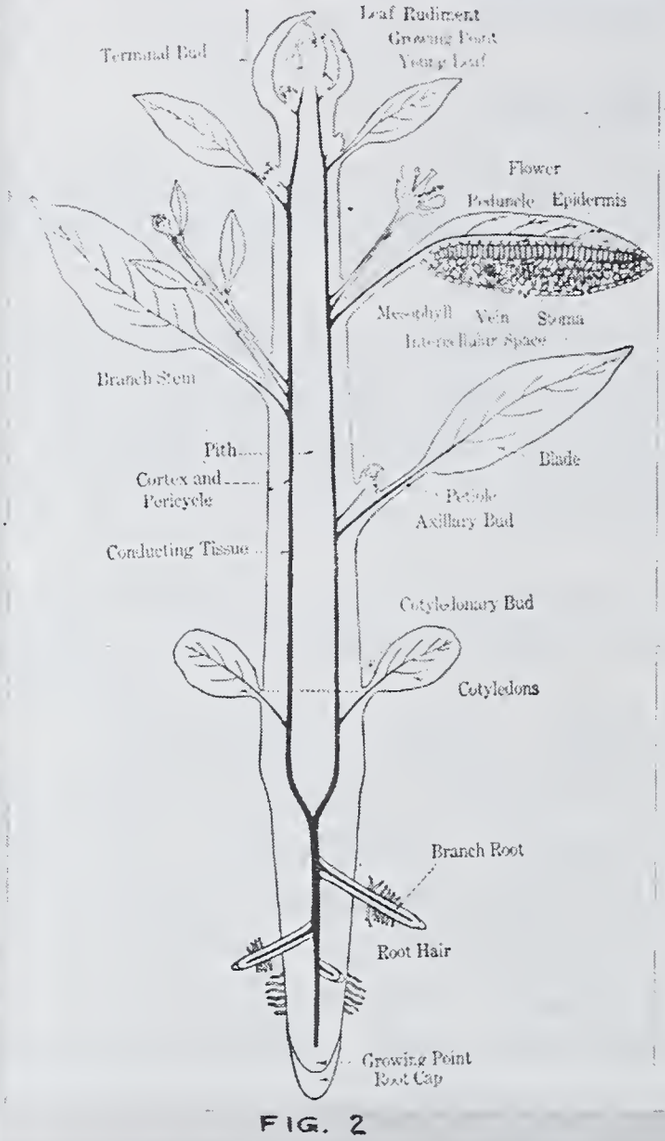

FIG. 2

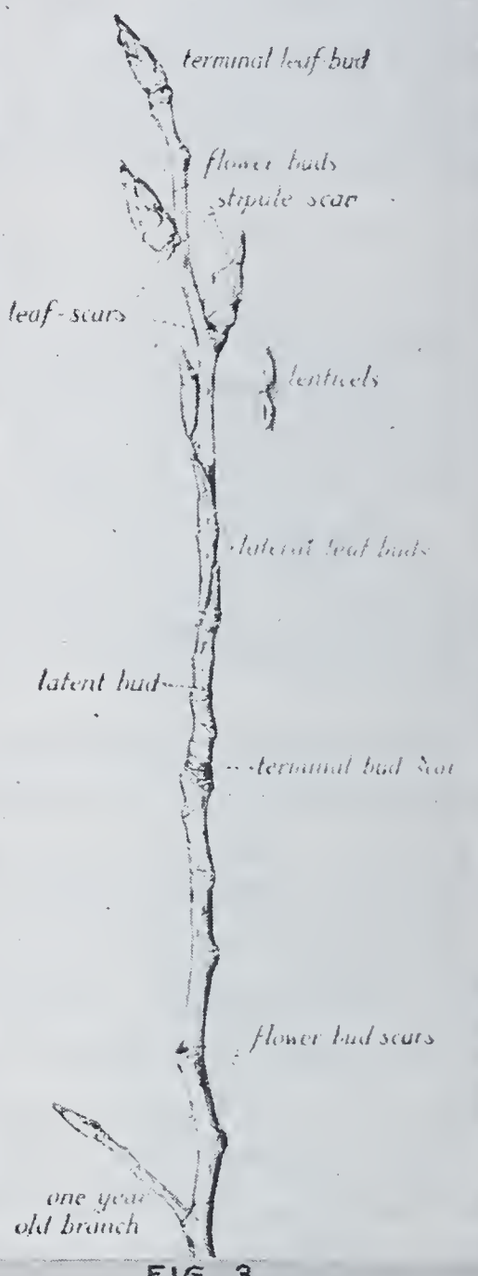

FIG. 3

Fig 1—Diagram of Starch-Making.
This is taken from Youngken, "Pharmaceutical Botany," P. Blakiston's Son & Co., who in turn took it (after Atwood).

Fig. 2—Diagram of the Body of a Seed Plant Such as a Tree Showing Its Principal Parts.
This is taken from Youngken, "Pharmaceutical Botany," P. Blakiston's Son & Co., who in turn took it (from Robbins, after Holman and Robbins).

Fig. 3—Cottonwood Twig, Two Years Old.
This was taken from Youngken, "Phamaceutical Botany," P. Blakiston's Son & Co., who in turn took it (from Robbins, after Longyear).

other parts of the tree, where it is either used or stored for future use. (See Fig. 1.)

Light is probably favorable, although not necessary, for protein formation. As a consequence, protein formation may occur in any living cell, but especially in foliage leaves.

The growing tip of the stem ends in a bud and other buds, or side branches which have developed from buds, are evident as we proceed backward from the tip. The side branches, in turn, possess buds and these may be more or less developed. The nearer we come to the apex of the shoot, the younger are the buds. (Figs. 2, 3.)

We may learn much by examining the well-preserved stump of a transversely cut tree. There are two prominent regions, of which the outer we recognize as bark and the ringed inner portion as the wood. (Figs. 6, 7.) The bark and the wood are separated by an inconspicuous layer of growing and dividing cells, known as the cambium. (Fig. 7.) If the stump we are examining is a short one, that is if the tree has originally been cut near its base, then by carefully counting the growth rings (Figs. 6, 7), we are able to form some estimate of the age of the tree, allowing one ring for one year. The wood, itself, is made up of long tubes, shorter cells and taper-pointed wood fibers. The long tubes called tracheæ were the principal agents in the conduction upward of crude sap when the tree was alive; while the fibers gave strength and elasticity. The outer region or bark is composed of distinct zones. The outer part of the bark is corky and constituted a waterproof covering of variable thickness, while the inner part next to the cambium was really a conductive region, some of whose cells or tubes carried the elaborated food made in the leaves to various other parts of the plant.

At certain times, flower clusters or inflorescences arise whose position and structure are characteristic of the species of tree. Each flower is composed of certain whorls of modified leaves (Fig. 2) called in order passing from without to within—sepals, petals, stamens or male parts, and carpels or female parts. Not all flowers have the complete number of whorls, however. For example, in some species, the stamens may be lacking and the flower is then called pistillate. In others the reverse is true and the flowers are staminate. The sassafras and the willow have staminate and pistillate flowers borne on different plants of the same species, while in the case of the maple, both staminate and pistillate flowers as well as flowers containing both stamens and carpels, are found on the same tree. Stamens

produce pollen grains, which in turn develop the male germ and, from the basal part or ovary of the carpel or carpels, is developed the fruit. Sometimes other regions near the ovary wall are connected to it and aid in fruit formation. Inside of the fruit are found one or more structures known as seeds. Each seed usually contains an embryo which is the result of an union between a female germ or egg and a male germ or sperm developed by a pollen grain. If proper conditions arrive, the embryo may grow and escape from the seed, developing in time into an adult plant like the one from which it sprang.

Let it be said in finishing the picture of the tree that every living part of every plant from the toughest fruit to the softest flower and from the highest bud to the deepest root is constantly breathing and,

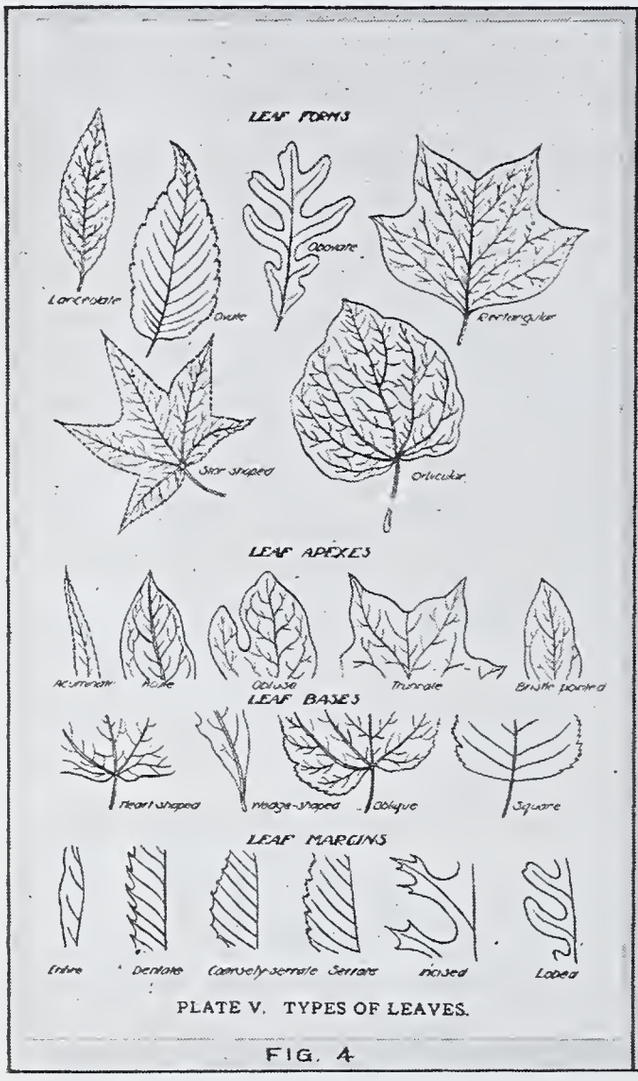

FIG. 4

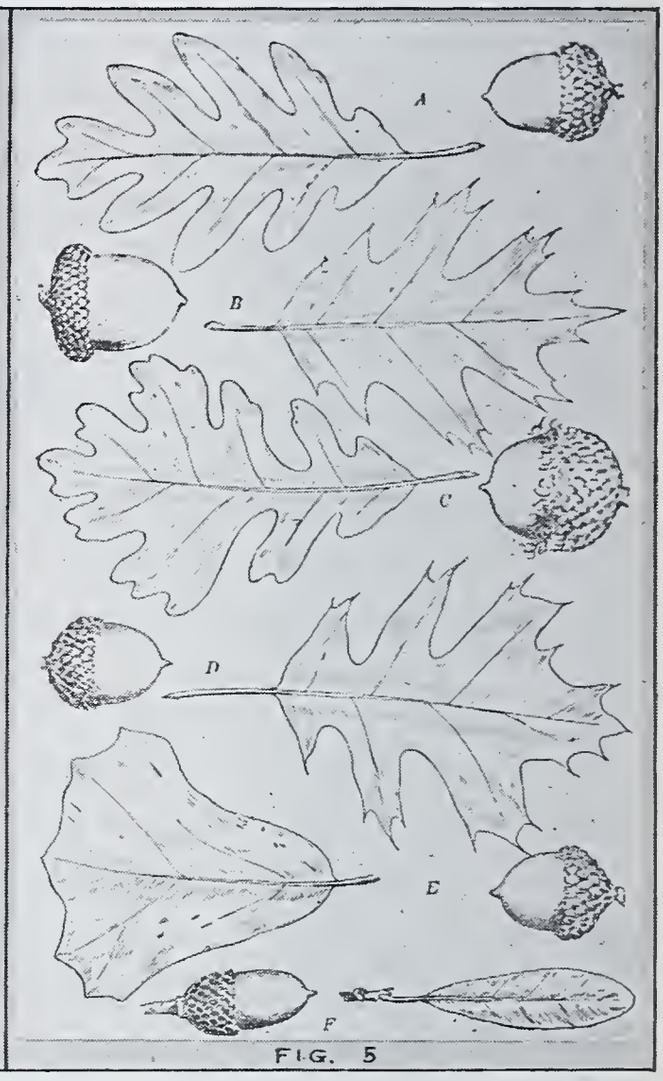

FIG. 5

Fig. 4—Types of Leaves.

Taken from "Pennsylvania Trees," by Joseph S. Illick. Bulletin issued by Director of the Commissioner of Forestry, Harrisburg, Pa.

Fig. 5—A Group of Leaves and Acorns Illustrating Some of the Differences Between Six Species of Oak; A, White Oak; B, Red Oak; C, Bur Oak; D, Black Oak; E, Blackjack Oak; F, Live Oak.

Taken from Haupt, "Fundamentals of Biology," McGraw-Hill Book Company, where it bears the legend (from Bergen & Caldwell, "Practical Botany," Ginn & Company, after Hough, by permission).

by so doing, is liberating energy which it uses in its life processes—without which life would be impossible. In short, each living tree has those peculiar properties which are common to every other living thing—plant or animal: structure, ability to use food and dispose of waste products, response to stimuli and reproduction.

E. Identification

"What tree is that?" is a commonly heard question which is too often answered by a shake of the head. True, many people recognize certain usually found trees, such as the buttonwoods and maples of our yards and streets, but even here confusion often results when the tree is devoid of one or two especially distinguishing features, such as leaves or fruits. And even, when known, a maple is often only a maple without certainty as to whether it is a silver, sugar, Norway, red or other species of maple. The study of trees in winter is just as fascinating and interesting as in other seasons, but it is often necessary to form judgments without the aid of the chief identifying characteristics before mentioned. In your study of trees, do not depend entirely upon the information given by a few parts, no matter how indicative, but obtain as much knowledge as possible before drawing conclusions concerning the following parts: general form, bark, twig, buds, leaves, leaf scars and bundle scars, wood, flowers and fruit.

a. *General Form:* People who are familiar with trees are able to recognize certain ones at a glance, even though some distance away. This they do by their characteristic form or appearance. It becomes a game to sit in a moving train or automobile and, looking at the passing vegetation, to say "that is an oak" or "there is an elm," and many hours of otherwise tiresome traveling may be frequently passed pleasantly and profitably. Of course, to do this with any degree of skill, it is necessary to have marked previously certain trees of known identity in your neighborhood and to have studied them from time to time, throughout the year. A tree devoid of leaves appears to be very different from a fully clothed one. Classified according to branching, trees fall into two groups: the first includes those which have one central trunk, like we observe in the pines, while to the second division belong those trees, such as the elm, in which the main trunk divides near its base into a number of more or less equal branches.

b. *Bark:* Bark, as has already been stated, may be divided into two zones (Figs. 6, 7): the inner is conductive, while the outer is protective. The outer region is protective, owing to its corky formation which guards against the excessive loss of water, and prevents the entrance of parasitic insects. Young bark, before the cork develops, is greenish, and in the case of sassafras, the green color is retained for a long time. As bark ages and thickens, it may become rougher and looks very different. The characteristic appearance of the buttonwood, a tree common on our city streets, is due to the dark-brown outer bark peeling off and allowing the greenish or yellowish bark inside to appear. In some species, like the beech, the bark remains smooth throughout life but in many other cases it roughens and cracks and peels off in a definite way as time goes on. Thus the bark of the beautiful paper birch peels off in layers like paper. Scales are formed in the pines and spruces, and shreds in the white cedar. Characteristic furrows and ridges appear in the bark of many trees, such as the black gum.

c. *Twigs:* Twigs usually are small branchlets representing the current season's growth and have taken their origin from vegetative buds which were located terminally or laterally on the twigs of last season's growth. If a twig develops from a terminal bud, it becomes a leader and usually develops faster than if laterally placed. Young

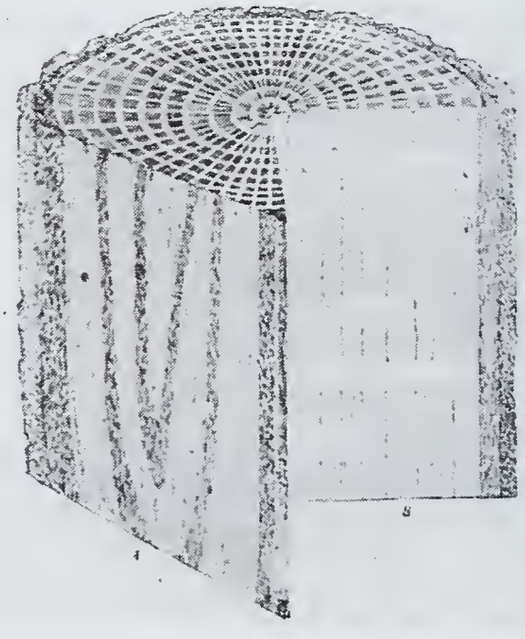

Fig. 6—Diagrammatic Drawing of an Oak Log, Showing Cross-Section or End View of Log, a View of a Surface (Tangential) at A Made by Sawing Off a Slab From the Side of the Log, and a View of a Surface (Radial) at B, Made by Sawing From Periphery to Center.

Reprinted by permission from "Botany with Agricultural Applications," by John N. Martin; published by John Wiley & Sons, Inc.

twigs are at first greenish, but gradually change color as they get older and the outer bark develops. Special little openings, known as lenticels, in varying number, may be present which allow the interchange of gases and thus help in the vital processes. Lenticels may be raised above the bark, as in the elder, or they may be level with it. We are all familiar with the short transverse lines found on the bark of cherry trees and birches. These are due to lenticels which are so united as to produce this result. In addition to lenticels, twigs may be hairy and possess scars where leaves or scales have been attached and have dropped. (Fig. 3.)

Something may also be learned by a study of the pith at the center of the twig. Although small, in some species, this may be large in proportion to the size of the twig as in sumach or in sassafras. Its outline in cross-section may be star-shaped, as in the oaks; three-angled in the alder, circular in the elm and ovoid in the linden. Its color, too, is important for it may be white as in the sugar maple; greenish as in the shad bush; red as in the Kentucky coffee tree, or brown as in the striped maple.

d. *Buds:* Buds are short young shoots or growing points with tiny leaves arranged upon them. (Fig. 3.) They are one of the ways in which the plant answers the threats of winter. Within the overlying scales or sticky substances of the bud, as the case may be, the embryonic growing point is protected from cold, and the following spring, when low temperatures have disappeared, opening takes place and growth and development starts. The amount of protection that a bud needs varies with the plant and its location. Buds which have no scaly covering are termed naked buds. Buds may be of three kinds, according to future development: a leaf bud, developing into a leafy branch; a flower bud, producing a branch with one or more flowers; or a mixed bud, forming a branch with flowers and leaves.

In position, buds may be terminal at the end of the stem; lateral or axillary, that is, arising in the crotch of a leaf along the side of the stem; accessory or extra, which form in or near the leaf axil as in young red maple; adventitious which are produced in unusual places. Lateral buds may be placed alternate to each other on the stem or they may be opposite or even whorled. Terminal buds may be solitary as in the beech, or in groups, as in the oak.

In size and form there is a great difference. Some are long, slender and sharp pointed, as in the beech; some are spherical, as the

terminal flower buds of the dogwood. Some buds may remain undeveloped for years, but given the cause, such as too much food or death of a number of terminal buds, and they may become active again. In other words, they constitute one of nature's "factors of safety."

e. *Leaves:* A typical leaf is composed of a flat, expanded green portion known as the blade or lamina, a stalk or petiole and leaf-like appendages called stipules. Leaves vary greatly in size and shape. Fig. 5 is given to show how the leaves may characteristically vary among different species of the same genus—oaks in this case—and by no means are all the different species of oak shown. It is impossible in the time and space allotted to this paper to do any more than to generalize in a brief way. Many trees are commonly recognized by the leaves which they possess.

Leaves may be either simple, as in the maple where they are composed of a single blade, or they may be compound, as we see in the locust, where each leaf is divided into smaller divisions, or leaflets. Leaves may be opposite each other, as in the maple, or they may be alternate, as in the chestnut.

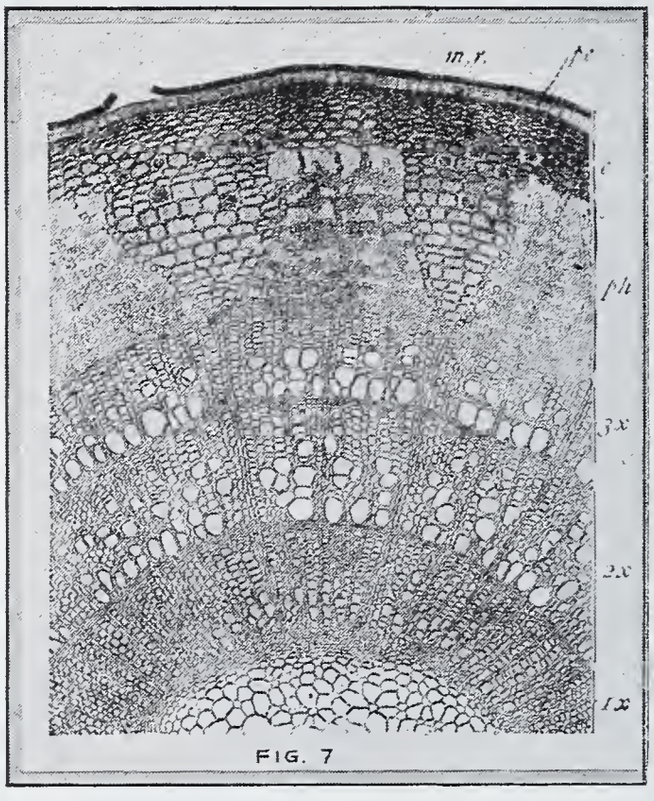

FIG. 7

Fig. 7—Representative Portion of a Transverse Section of a Linden Stem, Three Years Old; 1x, 2x, 3x, Successive Annual Rings of Wood; ph, Inner Bark With Fibers Showing as Lighter Parts and Conduction Tubes as Darker Parts; c, Cortex With Crystals; m.r., Spreading End of a Primary Medullary Ray; pe, Cork.

Illustration from Youngken, "Pharmaceutical Botany," P. Blakiston's Son & Co. (from Small, after Kuy).

In the description of any leaf, attention should be given to the general outline, that is, the form viewed as a whole without regard to marginal indentations; the type of point or apex; the kind of base; the characteristics of the margin; the system of veining; and the texture of the leaf. Textbooks and reference books use a long list of terms which are applicable to the various types of the characteristics above mentioned. A list and explanation of these are out of place in this paper and the interested reader is referred to "Pennsylvania Trees," (3) page 44, or to any complete botanical text, such as "Pharmaceutical Botany," by Youngken (7). Fig. 4 used with the kind permission of Dr. Illick, shows a few types.

As winter approaches and as the leaves of deciduous trees are assuming their coats of yellow, brown and red, a zone of thin-walled cells is formed across the base of the leaf stalk with the result that, when the time arrives, even a slight breeze will break the hold of the leaf upon the tree and it will flutter earthward. An examination of the scar left where the leaf was attached will reveal a protective corky covering.

f. *Leaf Scars and Bundle Scars:* Trees which shed their leaves in winter are known as deciduous trees. Whenever a leaf is shed a scar is left behind where the leaf was formerly attached. This scar is known as the leaf scar (Fig. 3), and, since also the bundles or conducting elements which passed from the branch or twig into the leaf must also have been broken in the dropping off of the leaf, we must find the scars of these within the leaf scars. The last-mentioned scars are known as bundle scars.

Leaf scars are arranged just as the leaves which come before them and they are diagnostically helpful, especially in winter, because in different kinds of trees they vary in size, shape, position and in the number of bundle scars they contain. For example, the leaf scars of the sourwood are alternate, nearly triangular, with a single compound bundle scar, while in the case of the white ash they are opposite, semi-circular, with numerous small bundle scars.

g. *Wood:* This region of trees is developed inside of the cambium ring (Fig. 6, 7). It must be remembered that the cambium is the zone of actively dividing cells. Those cells which are formed to the inside of the cambium each year become the elements of the wood. In spring, growth is active and large vessels are produced with but few wood fibers of small diameter. In summer and autumn the reverse is true and smaller vessels together with many wood fibers

appear. The result is the open wood of one spring is in contact with the dense growth of the previous summer and autumn. (See Fig. 7.) Thus it may be seen that each year produces its own growth ring, delimited from the year before and the year after, and that the annual ring is a record of one year of growth of the wood.

Stems and then the larger branches yield the best wood. The quality of wood from the roots is poor. "High-grade material is usually obtained from the stems of valuable species which have attained a large size, are free from lateral branches, and possess little stem taper" (3). The presence or absence and arrangement of, if present, the large conduction vessels in the wood may be used as a basis of identification. There are three types: (1) non-porous, such as in the pine; (2) equal pored, as in the beech in which the pores are about of equal size and are found uniformly throughout the year's growth; and (3) unequal pored, such as in the oak, chestnut and linden, where the large pores are found in the spring wood only. (Fig. 7.)

Extending from the central pith and crossing the rings of growth are lines of cells known as medullary rays. (Figs. 6, 7.) These also vary in width and heighth. In the study of a specimen of wood, three types of sections should be observed microscopically—a transverse (Fig. 7), a radial longitudinal taken parallel to the medullary rays and, hence, passing through the center of the pith and a tangential longitudinal which cuts the specimen at a tangent to the circumference and, hence, at right angles to the medullary rays. In each section the arrangement of the wood elements and their structure should be noted.

Annual rings and medullary rays are important to man in connection with the furniture industry. Quarter-sawed or radially-sawed lumber is wood that is cut so that the broad surface of the board is parallel with the medullary rays and it owes its beauty to them. (Fig. 6-B.) Plain-sawed or tangentially-sawed lumber owes its appeal to the markings formed by the annual rings (Fig. 6-A).

As the wood elements get older and find themselves farther and farther removed from the cambium, they cease to function and die. Thus there may be two more or less differentiated regions of wood in most of our trees—the living sapwood near the cambium and the dead and often colored heartwood.

h. *Flowers:* Individual flowers differ from each other in time of appearance, duration, shape, size, color and number and relation-

ship of their parts. In addition, the arrangement of flowers upon the flowering branch is important. Thus, flowers of the walnut are structurally different from those of the tulip tree and arranged in a different manner.

Some flowers, walnuts, birches, oaks, etc., especially of wind pollinated plants, are relatively inconspicuous but produce great amounts of dry, wind-borne pollen. Other trees of which the tulip tree and magnolia are representatives, produce large showy blooms. Pollen grains, also, make an interesting and valuable study since they vary in form in different species of trees and yet are on the whole uniform for any one species. For example, the pollen grains of the sassafras are spherical while those of the pine are characterized by having two winglike extensions of use in buoyancy. With respect to inflorescence or arrangement of flowers, we have many types varying from the solitary flower of the papaw to branches with many side-stalked flowers (the longer-stalked and older flowers being near the base of the branch), in the locust to almost stemless flowers arranged along a branch (spikes) in the hickory, to the flat-top inflorescences of the hawthorn and to the compact knoblike heads of the buttonwood tree. For a further discussion of the subject, the reader is recommended to any good textbook of botany, such as Youngken's "Pharmaceutical Botany" (7) and to "Pennsylvania Trees" by Illick (3).

i. *Fruits:* Many common trees are popularly recognized by their fruits—that is if the person identifying the tree is fortunate enough to discover that the fruits are still associated with the tree. In this way an acorn means an oak, a chestnut bur a chestnut, a certain kind of winged key a maple, and for that matter an apple, an apple tree. Usually the fruit develops from the ovary of a single flower (simple fruit) although sometimes, as in the case of the osage orange, it is the product of a flower cluster (multiple fruits).

Some simple fruits are dry and break open, as those of the magnolia; some are dry and split, as the dry winged key of the maple; and some are dry and do not break open or split, as in the case of the nuts of the oak, beech, alder and chestnut. Other simple fruits are succulent and fleshy, such as the cherry, apple and quince.

Inside of the fruit are one or more seeds. Each seed should be studied as to its method of attachment to the fruit, the type of seed coats it possesses, its markings and the kind of reserve food it contains. For, as we have said before, inside of each seed is a little living embryo plantlet surrounded or provided with sufficient reserve

food so that upon the establishment of suitable conditions, nutriment may not be lacking for growth to take place. Each embryo consists of a minute main axis with root and shoot and one or two small seed leaves which in some cases may store a great deal of reserve food and in others may be comparatively poor, with the food stored in the cells located between the seed coats and the embryo. When germination begins, the insoluble stored food is converted through the activities of enzymes into soluble food and this is used to nourish the little embryo which begins to elongate, pushing its way out of the seed coat covering. The root portion grows downward, and the shoot portion goes toward the light, and as a result, the little seedling becomes established and will, if given the opportunity, develop into another plant like the kind from which it came.

It is hoped that the technicalities of description of the last few pages have not wearied or confused the reader since these details have been presented only in order that an idea might be given concerning the tools of classification. It is not necessary for the beginner to puzzle himself with a long list of hard names. By making the study of trees a hobby, and by keeping constantly at it, by becoming familiar with a tree here and there, and by now and then adding a few understood terms to the vocabulary, progress will be enjoyable and satisfactory. It will be a great advantage to the student if he is able to equip himself with a good pocket magnifying lens and, also, if it is possible for him to obtain access to one of the compound microscopes at the nearest high school or college.

F. Conclusion

The forest is forever influencing our life. From it, we obtain among other things: dyes; wood for fuel, houses, books, newspapers, furniture, machinery and even clothing; the skins of animals; and fruits including nuts. Telegraph a hundred miles and your message passes over 6000 poles of wood, and there are 3000 wooden ties to every mile of railroad. It is estimated that the coal mining industries of Pennsylvania consume 108,350,000 cubic feet of wood per year and that 306,000 cords of wood are annually used in cooperage and veneering in Pennsylvania.

Among the branches of the forest trees live the birds which feed upon insects hostile to our crops. The forest floor is covered and protected from erosion by the decaying remains of plants and animals called humus which absorbs and holds water from rains and melting

snows, thus slowing the run-off to the forest streams and preventing floods. Thriving industries, large towns and a progressive and a prosperous people result from well-managed forests.

The forest is a place of beauty and, with wise handling, will be a great influence for strong, healthy bodies and clean minds of our citizens. "If you are a citizen of Pennsylvania, you are one of the 10,000,000 stockholders in the State forests. This gives you permission to use the State forests to enjoy yourself. All that is required of you is that you obey a few simple rules and this every patriotic citizen is willing to do. . . . The aim of the State Department of Forests and Waters is to handle them so that they will produce continuous crops of forest products and bring a full measure of other benefits to the citizens of the State" (4).

In closing, may I leave this message with you: Become familiar with our forests, enjoy wholesome recreation in them, and obtain the benefits they give. In turn, cherish them and help to protect them against their enemies—insect, fungi, fire and heedless man.

REFERENCES

The following publications have been consulted in the preparation of this paper:

(1) *Bailey, L. H.* Standard Cyclopedia of Horticulture. Macmillan Company, London, 1919.

(2) *Foresters' Conference.* Commonwealth of Pennsylvania. Bull. 39, Dept. Forests and Waters, 1929.

(3) *Illick, Joseph S.* Pennsylvania Trees. Harrisburg, Pa., 1919.

(4) *Illick, Joseph S., and Shoemaker, Henry W.* In Penn's Woods. Bull. 31 (Third Edition, revised). Commonwealth of Pennsylvania, Dept. Forests and Waters, 1928.

(5) *Rogers, Julia Ellen.* The Tree Book. Doubleday, Page & Company, Garden City, New York, 1920.

(6) *Wirt, George H.* Lessons in Forest Protection. Bull. 35 (Revised). Commonwealth of Pennsylvania, Dept. Forests and Waters, 1927.

(7) *Youngken, Heber W.* Pharmaceutical Botany. Fifth Edition. P. Blakiston's Son & Co., Philadelphia, Pa., 1927.

TRANSPARENT LIFE

By Dr. Arno Viehoever

TRANSPARENT LIFE, obviously, implies a visibility or transparency of life, that is of those processes, usually much obscured, which we recognize as life.

Dr. Arno Viehoever

The most trying feature of life is the complexity and mystery of its organization. Even many scientists despair of ever clearly envisioning the whole melee of atoms in the organization, causing man to act as man, animal as animal, plant as plant. Analysis of the complexity of life discloses the merging of the vital into the physical phenomena. Applying fundamental physical laws to these phenomena we find the explanation for many phases of life. It is even believed that life as a "a new thing" may emerge when a certain stage of complexity is attained.

What this stage is remains uncertain, although Dr. Crile has just created "autosynthetic cells" from brain extracts. We accept for the present as the fundamental units of all matter or energy the protons and electrons with positive and negative electrical charges. Life then may be physiologically defined as a complex system of energy transformations. These transformations take place in small units, the cells, the structural building stones of these complex organizations we know as plants and animals. These cells themselves are inconceivably complex. They contain, of course, chemical compounds of varying complexity, which take part in the interplay of living tissue. The actual machinery set to work in the life process is usually obscured to our eyes. With a knife we may separate the tissue parts, with a test tube examine their contents. This, though, is no longer study of life, but of dead tissue—and the study and our understanding of life "in vita" is made extremely difficult.

The use of Roentgen rays has been justly hailed as a remarkable aid in the direct study of life, as it brings out certain tissues by shadows of varying degrees. Especially with the development of

the fluoroscope, permitting instant observation of certain inner organs and bone structures, the interpretation of life functions has been facilitated.

Even more helpful, however, has been the realization that the extraordinary transparency of some forms, plants as well as animals, low and highly organized, the surprising transparency of some tissues in plants and animals, might be used in the study of life. In fact the results already attained have exceeded our anticipations. The survey, however incomplete, of transparent forms and tissues found in the plant and animal kingdom has opened our eyes for many new opportunities in the fascinating observation of life's machinery in motion and in action.

Possibly most one-celled organisms are more or less transparent. Thus with the aid of the microscope the inner structure of germs, which may cause disease or bring about desirable changes in their environment has been observed. But even with the highest attainable magnification we soon realize the limitations which confront us in the observation and study of forms so apparently simple. We may assume that in the multitude of modifications, adopted in the adjustment to environment, transparency has been developed—at least for some of the higher organized forms as a protective measure. At any rate we find transparent forms, plants and animals prevalent in water.

Fig. 1. Stage Setting for Aquatic Plant—and Animal Life.

In Background: Fine Filaments With Spiral Pigment Bands of Pond Scum. (Spirogyra.)

In Foreground: The Bladderwort (Utricularia) With Leaves, Stems and Bladder Traps.

On Bottom: A Dead Leaf. (After Myers and Mueller.)

Unless we examine a drop of scum water we would scarcely expect to find this apparent scheme of protection by means of transparency carried out so far. If we take a ride in a glass-bottom boat to a shallow place, as the famed seashore of the Catalina Islands, or

dive to the coral bottom of the waters near Key West, we behold a wonderful sight of the transparent submarine flora and fauna, never to be forgotten.

To illustrate to the general public the splendor of the micro-world found in pond water and at the bottom of such a pond, glass models, 100 times magnified, have been prepared by Mr. O. Mueller, working under the direction of Dr. Miner, for the American Museum of Natural History in New York. There these splendid models are on exhibition. Interesting pamphlets, dealing with a drama of the microscope and describing the life and forms of the outstanding representatives of pond life have been prepared. (See Figs. 1 and 2.)

I. Transparent Plant Life

POND SCUM

The most conspicuous growth in a pond, a sluggish brook or ditch, is usually the pond scum—or brook silk—Spirogyra, a tangle of floating tubular strands. They owe their green color to the spiral bands, varying in number, of chlorophyll. In sunlight and in the presence of the chlorophyll the carbon dioxide of stagnant pools is utilized in the synthesis of food as starch, while oxygen is set free. This process of photosynthesis may be readily observed; starch grains are readily seen within the bands of chlorophyll as well as the organized protein bodies, the peripheral cell plasma, connected by radiating strands with the cell nucleus, the vacuoles, including the central cellsap vacuole and those that rhythmically contract and expand and obviously serve digestion. Aside from the processes of gas production, food storage and food use, pigmentation and plasma function, we may also readily observe the processes of reproduction and the formation of new cells in these simple vegetative cells called algae. In addition to the vegetative division of elongated cells into two new ones we may also readily observe the sexual reproduction. Neighboring strands coming into close contact, sending out projections, which connect with each other, form pairs of cells. The contents of one cell by an ameba like movement pass through the connecting wall into the other cell. Through fusion of the cell and nuclear contents a spore, the sexual zygospore, originates. This spore has a thick resistant cellulose wall. When released into water under suitable conditions (by the decay of the filament) germination starts with the subsequent growth of a new plant.

BLADDERWORT

Among the most remarkable plants in the micro-world is the bladderwort, utricularia. The plant owes its name to the formation of bladders or utricules, small animal traps, growing on a translucent stem with slender, branching, spine-like but very delicate and flexible leaves. These traps, though not much bigger than a pinhead, catch the tiny animals and micro forms,

Fig. 2. A Struggle in the Scum.

At Right: A Spherical, Floating Colony of Rotifers (Conochilus), Clinging Together by Their Toes.

At Center: Bladderwort (Utricularia) With Bladder (in Nature But the Size of a Pinhead) Showing Captured Rotifer Inside.

At Left: Bladderwort Stem Covered With Small Fresh Water Algae. A Green Alga, Crescent Shaped, Closterium. A Filament of Pond Scum (Spirogyra) With Spiral Pigment Band. (After Miner and Mueller.)

swimming in the water. The trapdoor on the lower free corner of the bladder is very thin with a flexible edge, which gives way when crustaceæ as the so-called water fleas or other aquatic creatures as the rotifers or smaller forms of the group of protozoa—held by the spines and glandular hairs, come in contact with it. The animal drops through the open door, which closes again, leaving the animal to die and decompose inside. The inner cell lining of the bladder then absorbs the liquid for food.

Other translucent or transparent water plants are found in pond water as water thyme (philotria), with slender pointed leaves and graceful translucent green stems.

EELGRASS AND WATERPEST

These plants, eelgrass (valisneria), and waterpest (elodea), are found in standing water and are often collected or even cultivated for use in aquaria, for which they are very well suited. Both may be used to demonstrate the rotation of protoplasma within the cell. The rectangular cells of the leaves show a simple sapvacuole, surrounded by a protoplasma sac. A leaf, separated from the plant and immediately observed under the microscope, shows numerous disklike, usually non-moving, chlorophyll bodies, uniformly arranged below the outer cell wall, some on the back wall and apparently none at the side wall through which cells communicate. Within about an hour, or sooner if the plant had been exposed to the sun or to some heat, the chlorophyll grains move to the side walls in little streams of protoplasma. Then the accumulated plasma with all chlorophyll grains starts to rotate practically without interruption. The protoplasma movement of eelgrass has been observed best in the wide, elongated cells from the interior of the leaf, obtained in a section about half the thickness of the leaf. The rotation speed is hastened by slight warming of the slide, it circles around the cell, carries with it the green or yellow green colored chlorophyll grains. The direction of the plasma stream changes without any apparent cause or regularity.

OTHERS

Protoplasma movement has also been observed in the rootlike strands of chara fragilis and in the internodal cells of Nitella, both closely related fresh-water algae showing in their outer morphology much similarity to higher developed plants.

Plasma, as well as sap movement, may be observed in widely distributed water plants as the waterpest (elodea), and eelgrass (valisneria), already referred to, and frog's bit (hydrocharis morsus ranae). The hairs of the pollensacs of spiderwort (tradescantia virginica), the stinging hairs of the nettle (urtica), the roothairs of trianea are mentioned as suitable tissues to demonstrate protoplasma movement. Clearweed (adicea pumila, or pilea polosis), growing in swampy shaded places or woodlands, the half aquatic ludwigia found in marshy and swampy areas, jewel weed (impatiens), peperomia palucida from South America, pumpkin stem (cucurbita), birthwort (aristolochia clematitis), escaped from cultivation, celery and especially the inner leaves of lettuce heads are among the plants which have been found translucent enough, if not transparent, to observe the distribution of the conducting system and under specially favorable conditions the circulatory system in action.

II. Transparent Animal Life

The jungle of aquatic animal life becomes most interesting, when the inhabitants are viewed under the microscope. A drop of pond water, as intimated before, when seen through the window of the microscope, shows us a new world of life. Antony van Leeuwenhoeck, the young clerk in an Amsterdam clothier store, was evidently among the first with his self-made lenses to venture into this new world. Thus he saw countless numbers of minute creatures, hurrying to and fro, as determined as the creatures of our macro-world, on their errands of life.

BELL ANIMALCULES

Among the one-cell organisms, which behave more like animals than plants, the protozoa, we have, among others, one prominent representative of pond life—the beautiful animalcule "Vorticella campanula." It has a bell-shaped body with a disked crown of cilia, a distinctly visible cellular center, the nucleus, and contractile vacuoles. These serve for gas and food exchange, and may well be compared with the primitive digestive and respiratory system. By means of long, slender stems of protoplasma with an inner contracting thread of denser protoplasma, these animalcules are anchored to their support. Shaking the liquid, tapping on the slide, or disturbing the animals otherwise, causes the contraction of the thread, of the stalk to a spiral, of

the bell-shaped ciliated body to a ball. Gradually the ciliated bell expands again, the cilia start to "whirl," the stalk and thread relax and lengthen again. Thus we can observe the most primitive response of a living cell to its environment antedating the muscular and nerve actions of more complex animals.

FRESHWATER POLYPS

Generally distributed throughout the country in ponds and streams swarming with plant and animal life, and attached to stems, leaves or other subjects are found these freshwater polyps or hydras. They are gray, green

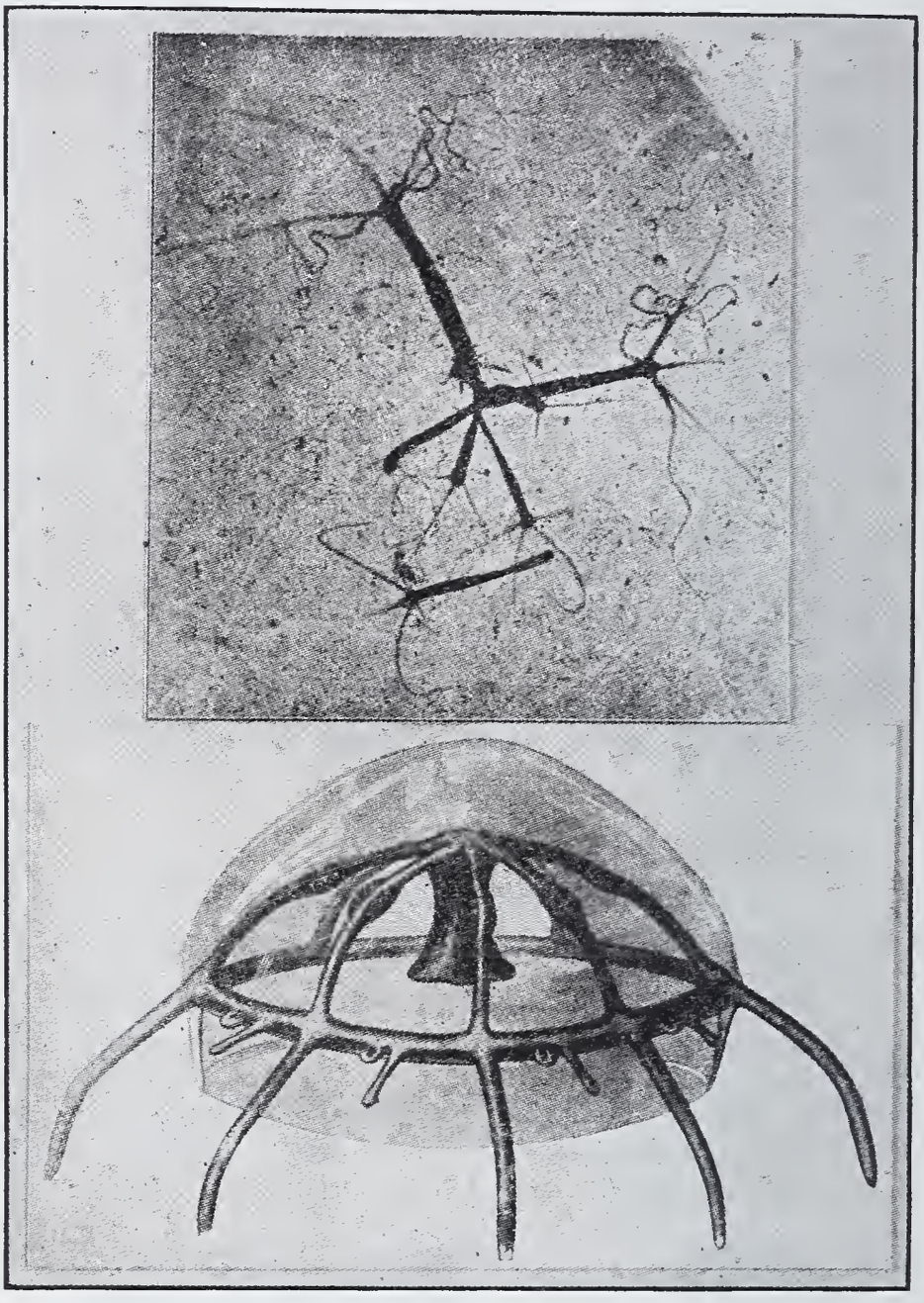

Fig. 3.

Above: Fresh Water Polyp Reaching Out for Its Prey. (After Hartmann.)

Below: Jellyfish (Medusa) With Its Elaborate Digestive Canal System. (After Guenther.)

or brown, slender animals of tubular form, one-eighth to one-half inch in length, which project from their stationary attachment. This fastening attachment is accomplished by a foot with an adhesive disk holding on to the object below the water's surface. At the upper end of the tube is a mouth, surrounded by a varying number of thread-like tentacles. Their length varies with the kinds or types. The hydra may leave its place and crawl or swim slowly through the water. In aquaria it may be seen on the side glass walls or even be collected on glass plates placed inclined into the water reservoir, simulating the conditions of the natural environment of the fresh-water polyps.

Special respiratory, excretory, digestive and circulatory organs, distinct muscular and nervous systems are considered to be absent. However, let us see how these simple animals function:

The animal's prey as insect larvae, newborn fishes, minute creatures of the shrimp family, is caught with the armlike tentacles, which reach out, sting and paralyze these little creatures with the sap of spiny nettle cells, located mainly in these tentacles. The bodies swallowed by the mouth, a small opening of the tubular hydra, passes into the internal cavity, the absorptive, digestive and circulatory sac. The digestion is furthered by the secretion of a digestive fluid from the secretory cells, lining together with other cells the cavity. The excretion is said to be carried on through the surface of the body wall, an inner layer, having besides the secretory cells, already referred to, cells with vacuoles and pigments as chlorophyll of chlorophyll-like bodies. These must enable the little water polyps to make their own food in emergency. The middle layer, through which the excretion passes, consists of non-cellular supporting cells, harboring the reproductive cells. The excretions finally pass the third, the outermost cell layer. The wall may be distended or contracted as needs require it. Respiration or the exchange of gases also proceeds through the body wall. Histologically the tentacles are hollow projections of the body wall. Fairly long muscle fibers and isolated nerve cells, interconnected by delicate projections are distributed throughout the animal body, but are most numerous in the tentacles.

When the tentacles or the body wall, especially near the tentacles, are irritated, the stinging organs, consisting of spiral threadlike tubes, lying coiled within the cavity of a special outer body cell, come into action. The poisonous paralyzing fluid in the sac or cavity is injected

into the animal by this coiled, spiral tube—now projected into the prey with a minute spine—a veritable injection syringe.

Well-fed hydras soon develop projections and branches of the body wall. These buds become perfect replica of the main hydra and soon begin an independent life. This same effect of sexless reproduction may be obtained by injuring or cutting the hydra in pieces. The pieces left of those torn off from a well-fed and vigorous specimen develop into new organisms.

The sexual organs originate from small "interstitial" cells, located between the outer body wall. They represent small male projections, producing spermatozoa, and large projections, the ovaries, each producing one large egg.

JELLYFISH

A somewhat similar weapon of stinging nettles is used by the jellyfish, highly transparent or translucent. It floats with its bell-shaped body and many nettling streamers (tentacles) near our ocean shore or in the tropical sea. It attaches itself to seaweeds and other objects by means of the nettle cells and adhesive pads, located near the outer end of the tentacles. It swims through the pulsating contraction of the bell body. Water taken into the prominent cavity is forced out again through the central opening.

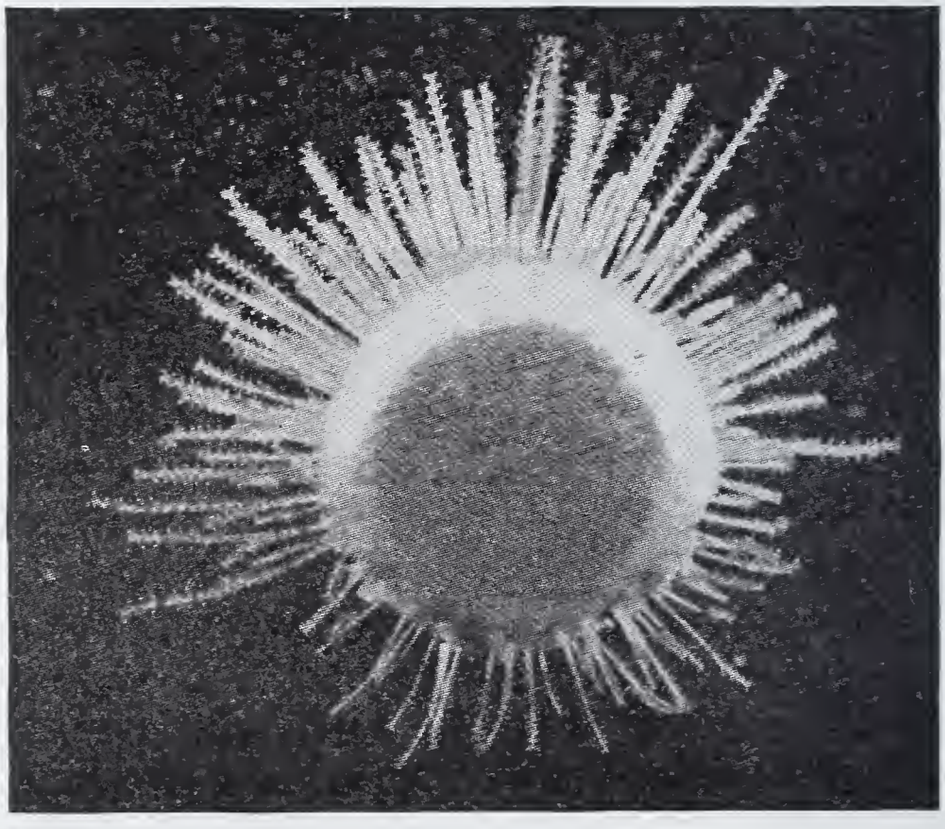

Fig. 4.
Jellyfish, the Glory of the Seas, With Its Dazzling Dangerous Arms. (After Pond.)

Muscle fibers distributed in the bell give the animal the power of this pulsating motion and thus the power of locomotion. Food is taken through the mouth opening of a short tube leading into the central "stomach" which is connected with tubes running to and, as a ring, around the margin of the bell or umbrella, the entire system functioning as the digestive apparatus. Nerve cells are distributed beneath the wall and in the perforated membrane covering the cavity. Hydralike larvae may bud from the walls in the asexual process of reproduction or they may be developed sexually from the eggs, fertilized by the male spermatozoa, formed in special organs. These are suspended beneath the radial canals. (See Fig. 3b.)

The nerve ring connected with the muscle ring around the bell margin, representing a concentration of nervous tissue for the control of the entire movement, has been considered by some authors as the central nervous system. The loose net work of nerve cells and fibers in contact with the nerve ring has been looked upon as the peripheral nervous system. Removal of the nerve ring causes paralysis of the animal. The excretion of apparent waste materials from the circular digestive canal to the exterior through minute pores may with others be considered as the first evidence of specialized excretory organs, not observed in lower animals.

WHEELBEARERS Probably the most conspicuous creatures in the miniature world of aquatic life in pond water are the rotifers or wheelbearers. (See Fig. 2.) Their tops or heads are wreathed with rapidly vibrating hairlike cilia in rhythmic motion giving the illusion of rapidly rotating wheels and suggesting the common name given. These "wheelers" have possibly first been described, though vaguely, by Rev. Harris in 1696, and then more fully discussed and demonstrated before an uninformed and unbelieving world by Leeuwenhoek. In spite of the seeming infinite variety, rotifers have certain characteristics in common. They are all minute and require moisture for active life. Some may be kept for years in a dried condition, only to revive upon addition of a little water. A firm film or cuticle, hardened to a shell, often protects the body. The body is topped or crowned by a circle of cilia and ends at its base in a taillike foot.

The Muscular System

The simple muscular system functions admirably. In case of the least disturbance the longitudinal muscles pull the heads down with the delicate crown of cilia. This quick response to disturbance in the form of contraction is obviously a means of protection. The foot, by means of adhesive toes, holds the rotifer attached to an object. The cilia are thus free to provide for food in producing such currents that food is brought before the mouth opening. If the rotifer is not attached the cilia serve locomotion as well.

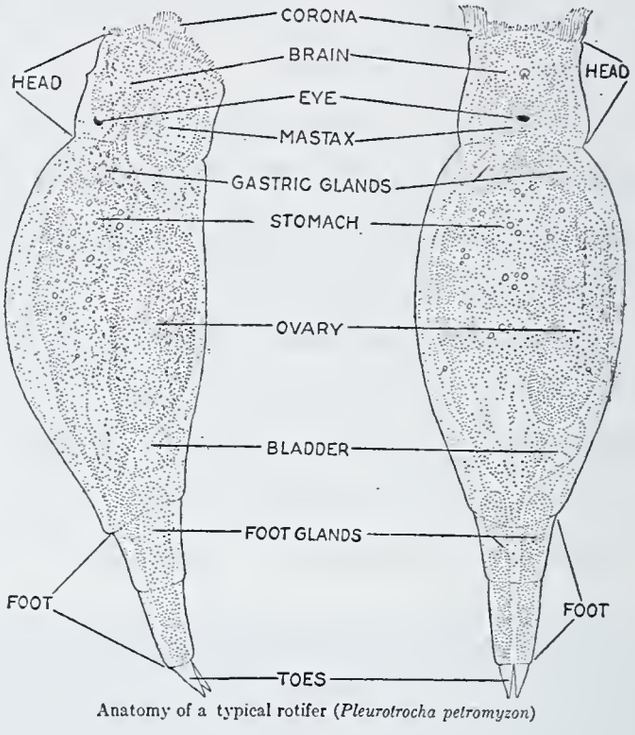

Fig. 5.

Anatomy of a Typical Rotifer (Pleurotrocha Petromyzon). (After Myers.)

The Digestive System

This system is also considered fairly simple. The mouth is located at the lower edge of the ciliated disk. A short esophagus (connection to the stomach) is provided with a jaw grinding and crushing apparatus (mastax) for food. These jaws are constructed of such resistant material that the precatory rotifers use them as pincers or tongs with needlelike teeth on the inner edges. They even can throw their jaws out of the mouth for offensive attacks. The crawling rotifers, living on leaves or plant stems, have a powerful muscle, contracting and expanding in a cavity serving as a pump with which the rotifers suck the cell contents from plants.

As the diet of the animal is about the same in all rotifers, we have practically the same function of the stomach into which all food

is emptied, after passing the masticating jaws. The large stomach is the most conspicuous organ in the body of the rotifers. The stomach wall is comparatively thick. The posterior part of the stomach leads into the intestine, a short, straight organ, into which the undigested residue passes from the stomach. The excreta are finally discharged through the cloaca located above the foot. The bladder is represented by tissue located near the cloaca.

The Nervous System

The nerves in this simple organization radiate from the brain, a central ganglion tissue in the head, to the different body organs. It is connected with one or more red eye spots. These nerves enable the rotifers without a complex nervous system to respond to external stimuli. Rotifers are attracted by light, require contact with a certain amount of oxygen and thus freely circulating water, and are very sensitive to wave action from which they must be sheltered.

The Glandular System

FOOT GLANDS

There are two or more glandular tissues, the "cement" or "foot" glands, which discharge a viscous fluid through ducts opening either at the lower end of the body or at the tips of the toes to enable the "wheelers" to hold on.

GASTRIC GLANDS

Two gastric glands, located near the stomach, are also usually present, assisting in the digestive processes.

SEXUAL GLANDS

The female and male glands are distinctly different. Male forms are much less numerous, in fact are believed absent in moss-dwelling rotifers. Even where they exist they are degenerate; they have, with the exception of a few cases, no digestive system and the very short life span of a very few hours. The female forms, normally developed within the body of the mother, emerge after a second generation has begun to mature in the ovary.

ASEXUAL REPRODUCTION

The eggs, usually developed without fertilization, produce within a few days a new generation of females. This process continues throughout the warm weather.

SEXUAL REPRODUCTION

In fall or winter some females develop a large quantity of small eggs; these produce males which then mate with the females. The fertilized eggs have a very tough skin, permitting overwintering through the cold months. Germination may then start again in spring. The resting eggs, becoming submerged by mud, are distributed from pond to pond through birds and waterfowls, as this mud adheres to legs and feathers, or passes unchanged through the digestive tract. Rotifer eggs are so light and small that they are easily distributed, especially by the wind, after the pools partially dry out and the restive eggs become exposed to the atmosphere.

THE LAW OF THE SCUM

As all other organisms in the pond teeming with life and submitting to the law of eat or be eaten, we find rotifers equally committed. They swallow their prey of one to multi-celled organisms as from protozoa to crustaceæ, and are in turn devoured by the crustaceæ, the worms and the fish. The rotifers also function as scavengers of polluting and decaying matter, disposing of the floating as well as the settled particles, animate and inanimate.

WORMS

Though not closely related with each other, the flat worms and the round worms, the unsegmented and the segmented, may be, for simplicity's sake, here briefly discussed together. Of special interest, for our purpose, are the aquatic earthworms, in as much as they are transparent.

Planaria, the fresh-water flatworm, is common in our pools, streams and lakes. Our textbooks tell us that here are well-developed muscular, nervous, digestive, excretory and reproductive systems—so constructed however as to function without the co-ordination of a circulatory and respiratory system, the coelom cavity and the anus. We might search in mud or top soil for transparent forms of nematodes, the unsegmented round worms with the central digestive canal and a nerve ring in the head serving possibly as a brain.

In mud of ponds, streams and on the bottom along the shore of fresh water or lakes we may also find the segmented round worms, among them representatives of the aquatic earthworms, Tubifex, found especially in the bottom sludge of polluted waters, and Chaetogaster diaphanous, about one-half inch long. It lives on decay-

ing organic material from swampy areas, leaves, stems, floating masses of algae as well as on certain crustaceæ as small daphnids or chydorus sphaericus (the commonest of all cladocera—so-called water fleas), found all over the world. In structure it agrees with the earthworm, the body is flexible, segmented by transverse groove and provided with bristlelike organs which assist in locomotion. A well-defined and somewhat extensive body cavity separating the alimentary tract from the body wall represents the digestive system. There are segmental excretory organs and reproductive organs similar to those of the terrestrial earthworm as well as buds from which the majority of new individuals are developed.

DAPHNIDS

The micro-world, first opened to man's view by the development and use of the microscope, included also the "daphnia." The Dutch physician Swammerdam is credited as having observed in 1669 a little animal with branching arms, moving in jerky, rowing motions in open water; the animal's name became pulex aquaticus arborescus. Later work showed its wide distribution in shallow pools—appearing in enormous numbers, then disappearing suddenly again.

There is apparently no other animal of so small a size, varying from less than one-fiftieth of an inch to over one-tenth of an inch in the largest known forms, that shows us so clearly under the microscope, or otherwise magnified, the wonderfully complex organization. The internal organs can be studied in detail, while the animal is kept in its normal environment.

General Structure

There is a distinct head; the body is covered on either side by a bivalve shell. The skin of this shell contains a protective substance, "chitin," so commonly found in insect wings. A single spine on the dorsal side, more resistant than the chitinous skin, and containing, as we found, some silica, prolongs the junction of the valves in daphnia. The head also has a prominent beak, not greatly unlike a nose.

Muscular System

The head bears two pairs of appendages, the antennae, main organs of the swimming locomotion with powerful muscles, occupying much inner space of the head. The basal joint bears two branches which carry long

hairy bristles. The size of the antennae, the number and length of the bristles, the size of the muscles, determine the type of locomotion. The smaller forms hop by more numerous and less vigorous strokes, the larger forms by rapid strokes with smaller antennae, and have an unsteady, somewhat rotating motion. Abnormal conditions, weakness or injury, by poison or otherwise, greatly affect the locomotion. A daphnid with but few lenses developed in the eye was seen to rotate completely through lack of properly balanced sight. Inability of locomotion is a striking sign of physical and physiological debility and may be used as a measure of injury.

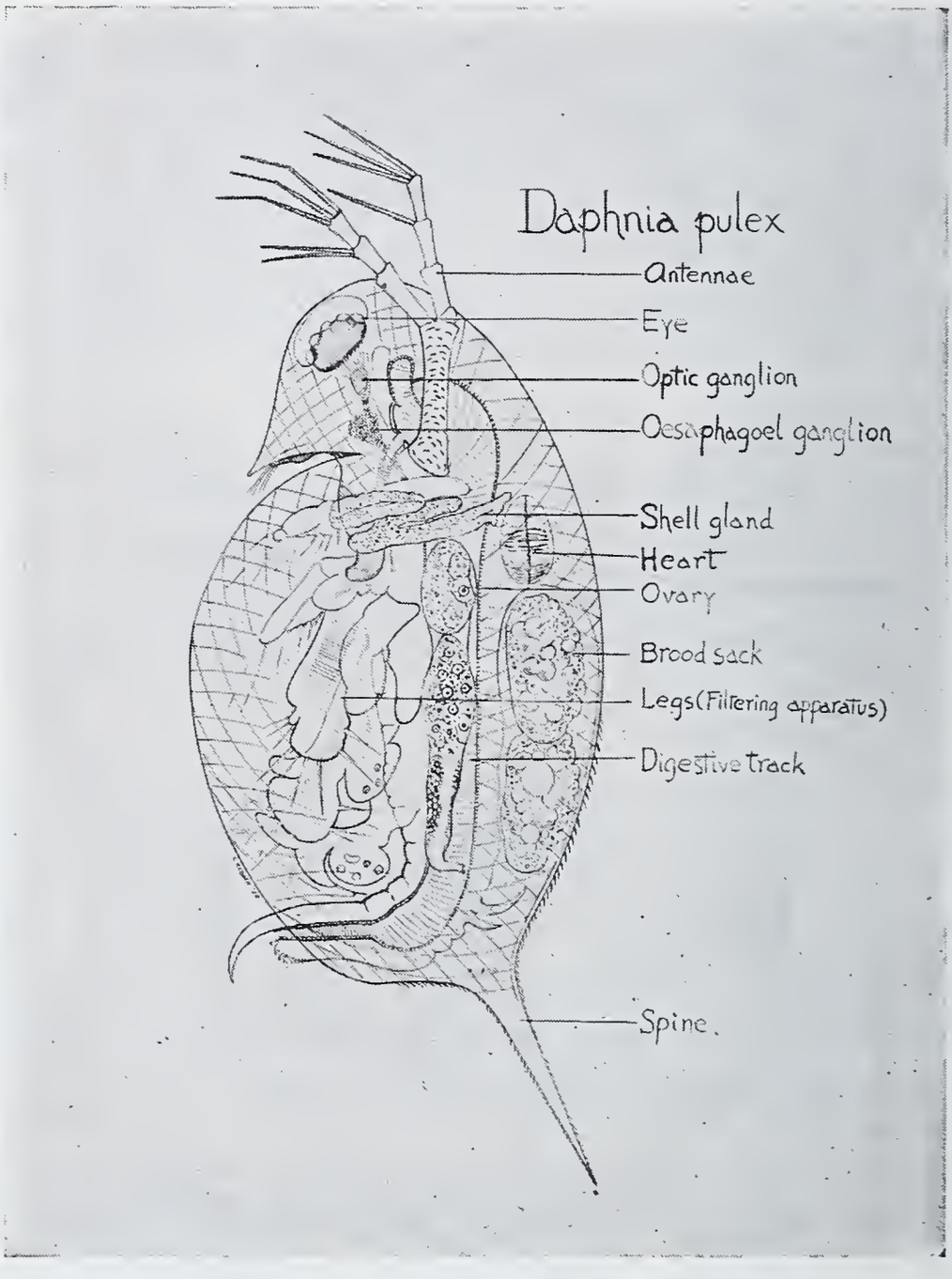

Fig. 6 Daphnia, an Ideal Representative of Transparent Life.

The Respiratory System

The body within the two valve shells shows a main structure, bearing five pairs of breathing legs. These are essentially leaf or featherlike gills, with numerous hairs and bristlelike extensions, creating a current of water through the valves to obtain their supply of oxygen needed for respiration, as well as particles of floating food. These gills present a very large surface to the surrounding water and the blood circulating through the gills is thus charged with oxygen.

The Digestive System

The food particles collected below the inner body structure and between the bases of the feet are fed forward through the mouth. Minute handlike structures, "mandibles," almost concealed on the ventral side of the body, push the food between the jaws. The opposing faces of these strong jaws are provided with teeth; the upper part appears stationary, the lower part is moving and grinds the food well. The jaws are attached to the rear of the head. The masticated food passes through the narrow esophagus and reaches the stomach, lying partly in the head. From the stomach the food passes without any marked interruption into the straight intestine. Stomach and intestine have a wall of striped muscles. Peristalsis, the involuntary movement in all animal digestion, except that of the lowest forms, is clearly visible. The rectum is closed and opened by muscles, the anus is located at the end of the post abdomen. The intestine is quite generally dark colored on account of its fecal contents. The post abdomen is connected to the body, and bent forward at the end are two terminal claws with spines or teeth. These spines serve to comb the legs and keep them free from foreign bodies, animate and inanimate.

The Circulatory System

The most fascinating unit, with the possible exception of the eye, is the heart. It is an oval or elongated sac which is rhythmically expanded and contracted. The pulsation, amounting normally to about 250 beats per minute, are easily seen in the living animal. The heartbeats are readily influenced and therefore may serve as an excellent physiological indicator for the condition of the animal.

The heart receives with each dilation from the body cavity the colorless or yellowish blood by an opening on each side—and pumps the movement of the blood corpuscles, readily seen, passes through it out in front with each contraction. As there are no blood vessels, the movement of the blood corpuscles, readily seen, passes through

a complex series of passages along definite courses—all over the body. This blood circulation is especially well seen in the head.

The Optical System

Daphnia has one large compound eye, the result of a fusion of two eyes, with numerous lenses inserted in more than half the circumference of the eyeball. The eye is moved by three muscles, readily visible—when magnified—on each side in either direction. Through the dark color of the pigment body, the remarkable size, the distinctly visible lenses, the constantly trembling motion, the eye is one of the most conspicuous parts of the head, if not the body. Injury to the animal is often visible in the eye, its movement becoming irregular, convulsive or paralyzed. Through sudden pressure the almost spherical eye lenses may be pressed out of their socket.

The Nervous System

The most conspicuous nerves, in fact, the only clearly visible nerves are those nerve strands which lead from the black retina of the eye to the brain, a fairly large tissue located in the head. From the brain lead other nerve strands through the body, following, as reports go, the ventral side of the intestine. A branching system of protoplasma strands has been observed, but its nature is obviously muscular, though the nerve tissue is likely closely connected with it. Sense hairs are placed at the sides of certain appendages, located in pairs at the head. Sense rods, or so-called olfactory hairs, are located at their ends. These peculiar sense organs, possibly transformed auditory organs or ears, probably help the animal to maintain its equilibrium. This same function may, however, also be taken care of by the small black point, located in the head near the brain and often referred to as the eye point.

The Glandular System

DIGESTIVE GLANDS

Two long, curved, colored sacs, located in the head portion and attached to the stomach, in fact, communicating with it, are said to function as the liver. Another pair of flattened yellow or greenish tubes, located below the heart, opening to the exterior near the mouth, the "green glands" or the "shell glands" are regarded as the kidney. Glandular cells have also been observed as a dark colored lining of the stomach and the intestine.

SEX GLANDS

Sexual reproduction, as in rotifers, plays such a minor role in the life cycle of daphnia that the male sex is usually dispensed with, unless conditions of environment require it.

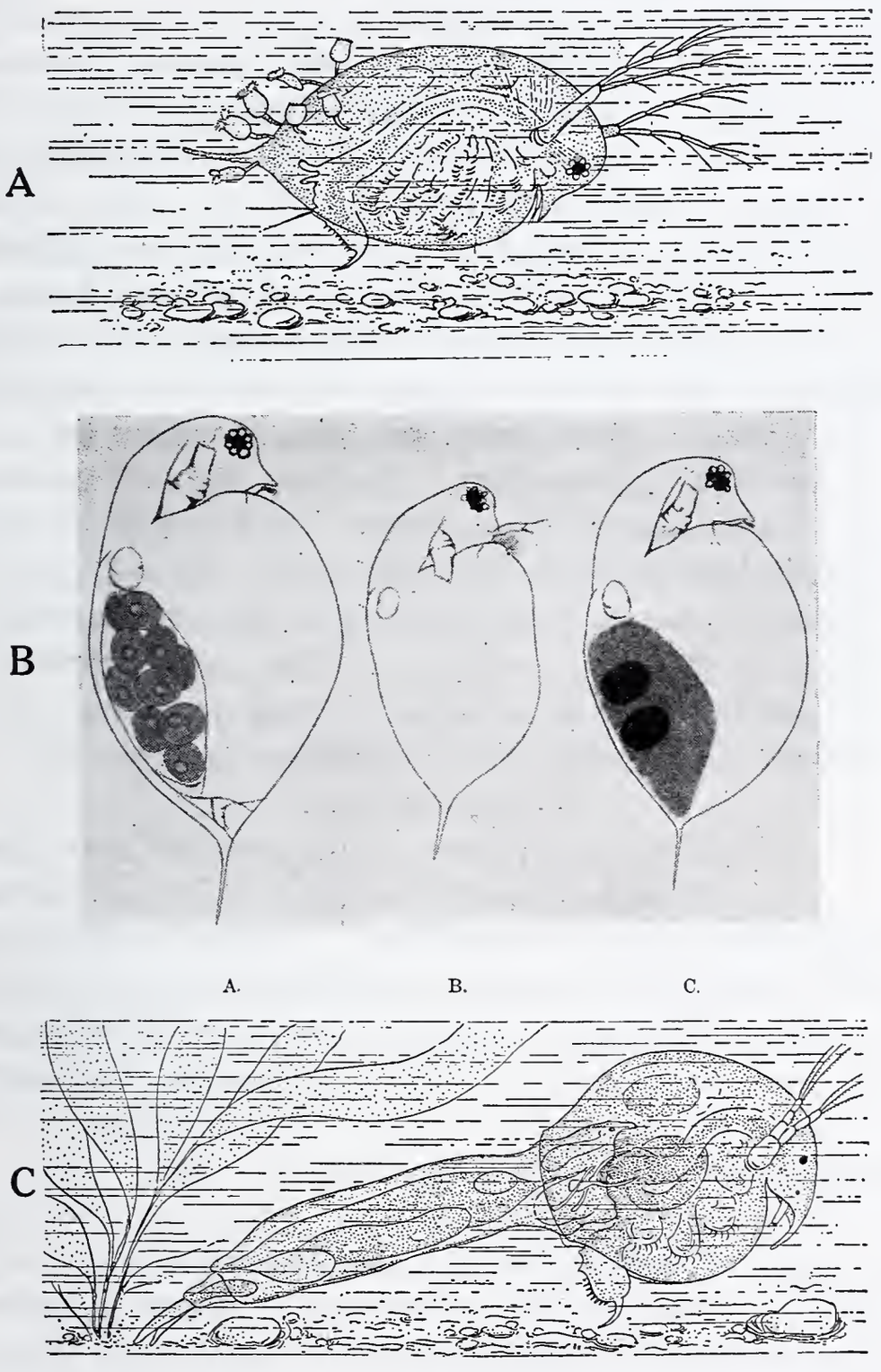

Fig. 7.

a. Small Rotifers (Brachionus) Riding on Daphnia, Holding on With Their Toes.

b. A. Female Daphnia With Asexual-Summer Eggs in Brood Sac; B. Male Daphnia Without Brood Sac; C. Female Daphnia With Sexual-Winter Eggs in Brood Sac. (After Banta.)

c. A Rotifer (Dicranophorus) Eating Its Way Into a Living Cladoceran, Using Its Powerful, Pincer-Like Jaws. (Fig. 7a and 7c After Myers.)

FEMALES

The cosmopolitan daphnid daphnia, if living in ponds, exposed to freezing, hatches in early spring from sexual winter eggs, produced during the preceding open season and fertilized by the copulation of males with females. The young daphnia are all of the female sex.

Within five to ten days, depending upon the temperature of the environment, each female becomes an adult, at most, one-tenth inch or so in length. The ovaries, tubular female reproductive organs, lie along the sides or below the intestines and communicate by means of short canals (oviducts) with the brood sac. The ovaries, with large ova in them, in groups of four, develop one egg, the other three serving as nutritive cells. The brood chamber, located in the dorsal region, encloses the asexual summer eggs, released from the ovarian gland. These summer eggs grow without fertilization within two to three days at room temperature to normally active females and are released in large numbers. We have observed broods of fifty animals and more than fifty in a single brood of daphnia magna, released in several successions of few days apart. (See Fig. 7b A.)

Crowding of the cultures, resulting in extreme scarcity of food, accumulation of excretory products, and low temperature of the environment, cause the formation of male young, from the very animals, which produce only females, when conditions are favorable.

MALES

The male daphnia is distinguished from the female through its somewhat smaller size, lack of the brood sac, larger sense organs, "antennulles," its more upright swimming motion, and through its modified post abdomen with the male gland and sex organ, not greatly unlike in form that of the vertebrates. A strong hook attached to the first foot provides the male with a means to hold and clasp the female. The curvature of the body facilitates the copulation. (See Fig. 7b B.)

FERTILIZATION

Crowding and the resultant scarcity of food, or cold weather, also cause certain females to produce one or two large winter eggs, deposited in their brood sac. These winter eggs ordinarily do not hatch unless fertilized, although Banta, eminent research worker, connected with the Carnegie Institution, Cold Spring Harbor, N. Y., recently observed "pseudo sexual" winter eggs which developed without fertilization. These winter eggs pass through a resting period. They have thicker shells, and are so resistant to

drying out and even freezing, that they may remain dormant for months until favorable conditions permit hatching. (See Fig. 7b C.)

THE DEADLY STRUGGLE

Daphnia, so abundant in the common environment of fresh-water lakes, ponds and puddles the world over, is beset with a host of enemies. We have observed the fish mold "saprolegnia," related to the well-known fly mold, infest and subdue daphnia cultures, especially when the medium became acid; we have seen rotifers infest and overcome the daphnia, we have seen worms as the aquatic earthworm or simple forms as the water polyps or even the one-celled protozoa stentor devour young daphnia, and know from long experience as well as from literature that daphnia furnishes a highly attractive food for fish. It is claimed that minnows cannot satisfactorily be grown without daphnia and therefore we see fisheries and individual fish breeders interested and engaged in the use and cultivation of daphnia. (See Fig. 7a and c.)

The transparency of a whole series of life functions permits a new use of this little animal, namely its utilization in physiological experiments and in the testing of drugs.

FISH

One might expect to find in nature many forms of fishes protected from other water creatures by the cloak of complete or approximate invisibility. A fairly comprehensive survey has resulted in the detection of only a few species which excell in transparency. The world's smallest fish, Pandaka—named pygmea on account of its small size—has been found in the Philippines. But the size of a large ant, namely six-sixteenths of an inch, this smallest backbone animal known has a slender and almost transparent body with prominent eyes.

TOPMINNOWS GUPPIES

Next in size comes probably the rainbow fish or guppy, a life-bearing top minnow introduced from Venezuela and named after Mr. Guppy, a friend of the collector. The mature, brilliantly marked males reach a length of about an inch, the drab-colored females one and one-half to one and three-quarters inches. The young at birth are about a quarter of an inch long and remarkably transparent. As they grow the tissues become progressively obscured with exception of the skeleton in the tail. Placing the fish under transparent light and keeping it directly in water in a suitable chamber, or keeping it moistened with

wet cotton, we can observe blood circulation, especially well in the tail. We can less clearly see the action of the breathing apparatus with the gills, constantly moving, the action of the heart, particularly from the under side of the fish, and least clearly the function of the digestive system and the reproductive organs.

GAMBUSIAS

The topminnows, "Gambusia," from the southern states and Central America are a little larger (about one-half inch). Here too the eggs are fertilized and hatched within the body of the female, the young are borne well developed and alive, from three-tenths to two-fifths inch in length. They are practically equally transparent as the guppies—in this early stage. They are more hardy to low temperature than the guppies and are bred for the effective destruction of mosquito larvae which they devour.

OTHERS

Other fairly transparent fish observed in American, and specially European aquaria, are the angel fish (pterophyllum scalare) from the Amazon River, less than one inch long in the specimens observed; pristilla ridlei, from East Indies, one inch long; short fish (Ambassis nama), from India, one inch long; "transparent fish" (tetragonopterus milineatus), from South America, two inches long; light blue fish (pyrrhulina guttata), from South America; Australian rainbow fish (Melonotaenia nigrans), from Australia, two to three inches long; red inked and striped cyprinodon (Haplochilus chaperi and rubrostigma), from India. Beebe found in great depths in the Sargasso Sea an eel as transparent as glass and a deep-sea fish with an enormously distensible stomach which can obtain prey larger than itself. Fowler found among the coral reef islands of Batavia Bay, Java, the shrimp fish (Centriscus strigatus), swimming vertically, head downwards, and being glassy transparent.

TADPOLES

If we direct our main attention to ponds and ditches we find the small, spherical, dark-colored eggs of frogs and toads, imbedded in a colorless, albuminous jelly. The eggs laid in spring or summer, dependent upon the types, are deposited in a round mass on grass, roots and sticks—or as a surface film. The development of the eggs in the various development stages may be observed directly. The embryo, at a certain stage, shows a differentiation in head, trunk and tail—and breeds through gills. It frees

itself from the jelly enclosing it, wriggles from object to object, attaches itself by means of a sucker. As the tail becomes longer and powerful this is used for a swimming organ. Inner organs, as the heart, the blood circulation and the skeleton, may still be seen by transparent light. When the hind legs appear and increase in size the gills degenerate and are replaced by the lungs. The tail is absorbed, the forelegs push through, the gills disappear, the animal requires atmospheric air from time to time, the mouth increases greatly in size—the tadpole has changed into a frog.

The tail of the tadpole is especially suitable for inspection of the capillaries and blood circulation by transparent light. The following method has been found satisfactory by various workers in the immobilization of the tadpoles without the use of narcotics. Two lumps of plasticine are placed on a slide and modeled in such a way that they hold the body of the experimental animal, tadpole or larva

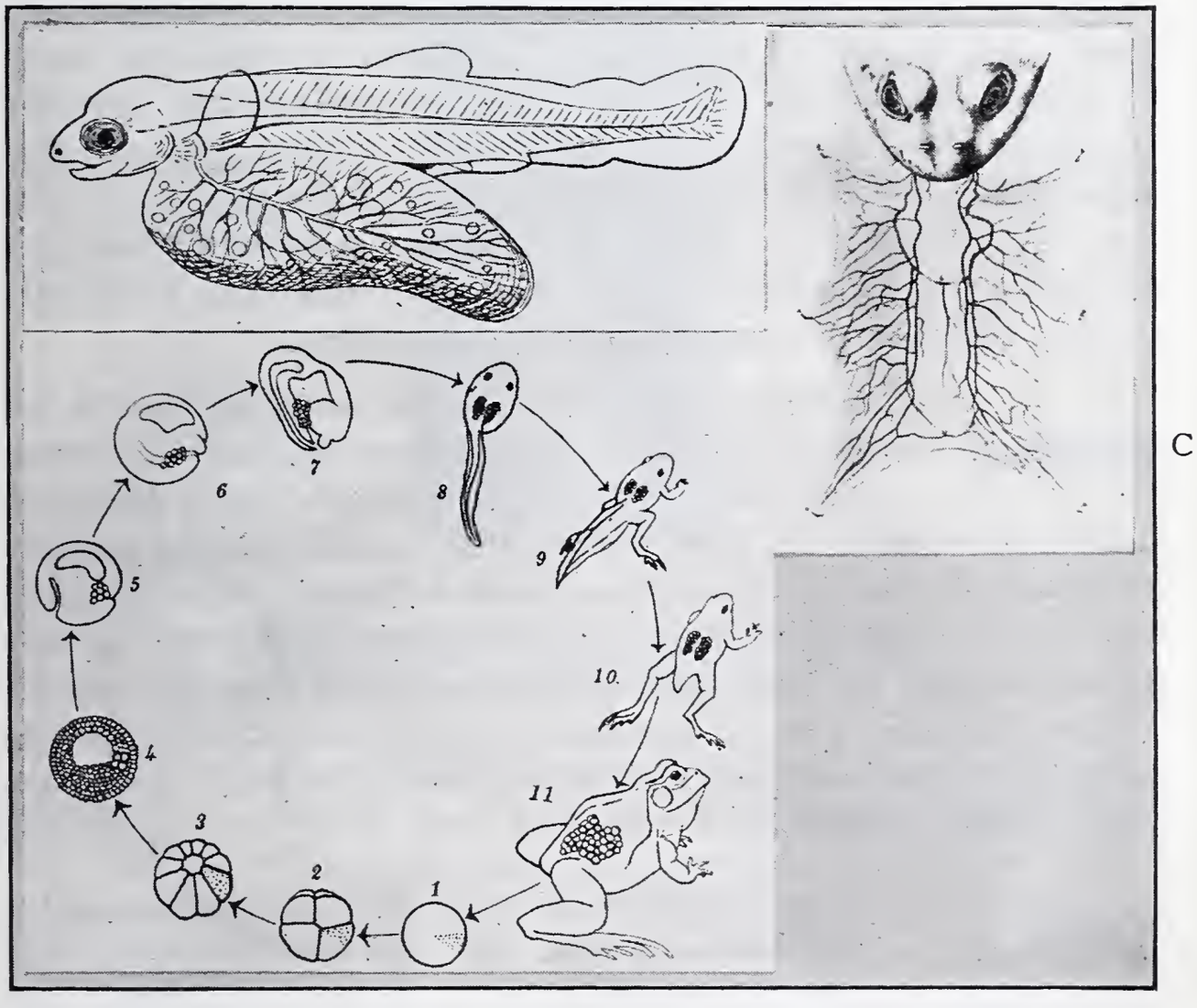

Fig. 8.

a. Freshly Hatched Trout With Yolksac Adhering to Body. (After Hesse-Dofflein.)
b. Development Cycle of Frog Eggs to Tadpole and Frog. (After Conklin.)
c. Frog's Tongue Pinned Out to Show Blood Circulation. (After Krogh.)

without exerting pressure. The tail is placed under a cover glass or a very thin sheet of mica, supported by plasticine feet. The body of the animal is covered with a narrow strip of filter paper, the microscope is tilted at a suitable angle and water is dropped on the filter paper once or twice a minute to keep the animal thoroughly moistened. Of course, specially constructed chambers, somewhat like Ziegler's water-jacketed compressor (E. Leitz, N. Y.), for running water may be used with advantage.

CHICK—EMBRYOS

We may readily follow the development of fresh, fertilized hen eggs and observe in the embryonal tissue such processes as blood circulation and heart action. In recent unpublished experiments Sister B. Mueller, working under the direction of Dr. Hammett, of the Lankenau Hospital, Philadelphia, obtained the following results which are helpful in guiding other workers as we have experienced ourselves. The eggs incubated at body temperature for a given time, were handled with special care during the examination. In order to reduce the shock they were handled as little as possible, temperature and moisture conditions were maintained by means of a temperature controlled water bath. Precautions were taken in opening the eggs for inspection so as not to injure the blood vessels, and to return the eggs, covered, to the incubator immediately after examination, in order to prevent chilling and evaporation of the egg contents.

36 HOURS INCUBATION.

About 75 per cent. of eggs had reached a fair degree of development. Blood islands, varying in number, were observed, but no sign of blood vessel formation or blood circulation. A heart was observed, however, in the majority of embryos. Only a few embryos showed a heart so far developed that the heart beat could be measured without removal of the embryo. In such a case the heart beat was seventy-three beats per minute. Where the embryo had to be removed from the shell to permit observation of the heart beat the shock of removal evidently caused the beat to drop appreciably.

48 HOURS INCUBATION

In practically 50 per cent. of the incubated eggs the circulatory system was established; some eggs showed markedly greater progress than others. The heart beat in the average was 112 beats per minute, the volume had increased as well as the vitality.

72 HOURS INCUBATION

The heart beat was now increased to 134 per minute. The study of the embryonal tissue, the blood circulation and especially the heart action was now made much easier through the progress in development and the increase in vitality. A number of such eggs were, after opening, covered up again as well as possible with the piece of shell originally removed and returned to the incubator. After twenty-four to thirty-six hours' incubation these same eggs were found still living and showed apparently the same degree of development as eggs not opened. Distilled water of the same temperature as the egg introduced in amounts from 0,2-1 cc. caused no apparent immediate change. However, in the course of several hours distilled water, infused in amounts of 1 cc., caused a release of blood through the capillary walls into the surrounding tissue and a material reduction of the number of heart beats.

Fig. 9.
Chick, Seventy-two Hour Development—Jewell Model. Blood Circulation With Vessels, Heart, Lung Bud, and Other Organs as Brain and Eye.

96 HOURS INCUBATION

The average heart beat was now 158 per minute, but the poor visibility of the tissues, due to their further development, presented a serious obstacle to the detailed study of the chick embryo, and specially the heart in vita.

From all observations the conclusions are drawn that there is considerable variation in the development of the chick embryo, that heart action usually precedes the formation of blood vessels, that the embryonal heart of eggs, after seventy-two hours of incubation has

a remarkable vitality and that this age of development—seventy-two hours of incubation at body temperature—is best suited for experimental work, the tissue being well developed without being obscured to observe such special functions as blood circulation and heart action.

OTHER TRANSPARENT ANIMALS

Having discussed various transparent forms of the animal kingdom, it may well be questioned what other forms of higher organized life may be found transparent enough for the intimate study of the organism "in vita," in the visible rhythm of life. Great familiarity with forms on land and in sea will permit, of course, a most satisfactory choice. It is quite obvious that a careful search in fields and shores, a study in marine and inland laboratories, special trips of exploration in any locality, including especially the tropical regions, would lead to the detection, if not discovery, of suitable representatives in practically every major group. Among the sponges we may have to look in Japan, where transparent forms have been observed; among the worms we might have mentioned Tomopteris, a segmented worm, noted for its transparency, or forms of Enchytraeus, another aquatic earthworm found in fresh waters of North America, whitish in appearance and seldom more than one inch in length.

From the group of molluscs we might select the young pond snail and aquarium scavenger, showing us a heart beat of eighty-six beats per minute, at room temperature; raising the temperature a few degrees the heart beat was increased to ninety-five beats per minute. From the crustaceae we might select cladocera species, other that Daphnia, or the heartless cyclops, the much larger sandhopper Orchestia, so common on our seashore, and its fresh-water relative, Hyalella—or the beautiful Phronima. From the large group of insects we could select the aquatic larvae of the may fly, or the mosquito larva, or the larvae of the Japanese beetle or the mealworm, though the inner tissues are much obscured in the terrestrial forms. From the lowest vertebrate animals we may select the Tornaria larva of Balanoglossus with a contractile heart, lying in a pericardial cavity, with a very simple blood circulation and digestive and excretory system.

Transparent Tissues

The higher we go in the organization and differentiation of animals, the less we find transparency of entire tissues. This is par-

ticularly true of adult forms. A rat at birth shows us a hairless body, red and fairly translucent. In the developed rat only the ear is transparent enough for the observation of the capillaries and the blood circulation.

The lower surface of the frog's tongue is covered by a smooth mucous membrane. When suitably stretched, the tongue, according to Krogh, shows a very wide-meshed network of capillaries, small arteries and veins. In the mouth the tongue is almost bloodless and usually pale. The tongue of the narcotized animal, if pinned out, becomes stimulated and a large number of vessels become prominently visible (see Fig. 8c). In the transparent tissue of frogs a normal circulation can only be maintained under strong illumination when the violet light of the visible spectrum is filtered out. The tissues evidently are extremely sensitive to light.

The web between the toes may be spread by means of triangles cut from object slides and placed between the toes. As transparent appendages the wings of butterflies, the ears of certain races of rabbits, rats, mice, the wings of bats have been used for demonstration with transmitted light. This light should not be stronger than necessary—and preferably have the red and the violet portion of the spectrum eliminated.

Internal organs may be exposed for observation by a small incision made with scissors at a point near the middle line of the abdomen, where no large vessels are found. The skin is lifted and the inner surface carefully inspected to avoid cuts of the then visible vessels. The transparent bladder is made to project through the opening. A loop of intestine is cautiously drawn out and exposed over a transparent stage, without the use of needles. Saline solution, as usual, keeps the specimen moist and clean.

It is generally conceded that the observation of normal circulation in internal organs of mammals by transparent light is extremely difficult. It is of prime importance to maintain the tissue exposed at the right temperature and moisture content. The human skin may be examined by reflected light, the transparency may be increased by placing a drop of paraffin oil or glycerin on the skin. Other workers have dehydrated the epidermis, then applied cedar oil, or removed the epidermis from a blistered skin and covered this with paraffin oil. Finally, the marvel of the human eye is at least partially transparent and may be readily examined in reflected light with special instruments.

Conclusions

There is a potential capacity in human beings for sensitivity to the wonder, beauty and infinite design of nature. As the great seers—Jesus, Buddha and others—we all may find strength and wisdom in the observation of nature, animate and inanimate. There are some to whom the love for life, for nature, becomes a conscious passion, and the study of nature, of life—in health, in disease—an urgent want, a daily prayer.

Lifting the veil from the ordinarily hidden stage of life, we have indicated how you too may see at least some of the inner machinery, muscles, nerves, glands, protoplasma, sap, blood at work, and witness their action before your eyes. To those who are interested in this spectacle, in the message of the very life in action, in its use for the study of drug action and drug standardization, our enumeration may prove helpful. Going beyond this scope, you may, with improved lenses, pierce now deeper into the mystery of the protoplasmatic mass. Transparent cells as those of the connective tissue taken from an embryonic chicken heart may be propagated and kept continuously alive and under observation. New transparent cell-like units, "Crile's autosynthetic cells," may be created from a mixture of the brain lipoids, brain proteins, and brain ash of freshly killed animals, showing the three fundamental characteristics of normal cells: irritability, respiration and reproduction over a period now of at least three months. The riddle of the basis of healthy growth, the cause of cancerous growth and of other mysterious diseases is attacked—yes, successfully attacked from every conceivable point of view.

Confronted with this world-wide, seemingly beehivelike activity of workers searching for a better understanding of life, all but carried along by the enthusiasm of those contributing, day after day, their bit to the amazing progress, called upon to join, at least in spirit, the forum of those who hope much from a study of life: life in vita—life transparent—need you hold back in despair of the outlook for ultimate control of the normal, the prevention, the correction of the abnormal?

This is the age of the "biological miracles," the door is already opened to the labyrinth of life.

THE STORY OF INKS

By C. C. Pines

THE ORIGIN of the written language is not known but from the earliest history of man many different means of recording and communication have been employed.

In Southern France, archeologists have discovered the relics of a pre-historic civilization where a semblance of domestic life existed which it is difficult for the modern mind to conceive of. Here, deep in his cavern home, the cave man, signaled to the future, his superiority over the wild beasts among which he lived, exercising that attribute which man alone possesses—the desire and ability to record his activities—by scratching into the rocky walls of his home, pictures of the very beasts he was forced to battle with for existence.

PICTURE WRITING

Thus, we see that far back into the past, picture writing was begun which later developed into the art of character writing where the writing was done on stone, clay or wax tablets by means of a sharp pointed instrument or stylus. The obelisks of ancient Egyptian antiquity, some of which are preserved to this day, are examples of writing done on stone. Doubtless some of my readers have seen Cleopatra's Needle, an obelisk of about 1500 B. C. which stands in Central Park, New York City. This stone antique bears inscriptions relating to the reigns of the ancient Egyptian Kings. Clay tablets were used to write upon by the ancient Persians and Assyrians and many specimens showing their peculiar cuneiform or wedge-shaped characters are displayed in museums at the present time.

THE FIRST INK

As civilization developed, the invention of materials to write upon such as the papyrus of the Egyptians was brought about. Papyrus, the earliest form of paper and the word from which the modern word paper is derived, was made from the fibers of the papyrus, a rushlike plant of the Sedge family. The invention of the papyrus necessitated also the invention of a fluid or semi-fluid capable of being used thereon, first by the brush and later by the pen. Thus, we have an inkling into the development of inks.

BURNT INK

The word ink is probably derived through a modification of the Latin encaustum which was the name given to the purplish red ink with which the Roman Emperors signed their edicts. Encaustum literally means burnt in. The signatures were, figuratively speaking, burnt into the edicts by means of the red ink. The French for ink is encre, the Old French enque and the Old English is enke or inke which words could have been derived from a shortening of the word encaustum.

For the cross-word puzzle enthusiasts, the fourteen letter word atramentaceous meaning inky, may be of use.

Ink is known to have been used by the Egyptians as early as 2500 B. C., old papyri (which are in existence today) dating back to that time were written upon with a black ink which was a mixture of lampblack and glue with a preservative to prevent decomposition. In China, the invention of ink is ascribed to Tien-Tchen, who lived between 2697 and 2597 B. C. China ink or India ink was made by the Chinese from the soot produced from the smoke of pines and the oil in lamps mixed with the isinglass of asses' skins and musk to correct the odor of the oil. The Chinese moulded their ink into cakes or sticks because of a scarcity of bottles in ancient times. The Hebrews and the Arabians had similar methods for making ink. Ink was used in Bible times for the book of Ezekiel, Chapter Nine, records the action of the man with the inkhorn. "And the Lord said unto him, (the man with the inkhorn), Go through the midst of Jerusalem, and set a mark upon the foreheads of the men that sigh and that cry for all the abominations that be done in the midst thereof." Ink here was used as a matter of life or death for if we read further we find the following passage, "Slay utterly old and young, both maids and little children, and women: but come not near any man upon whom is the (ink) mark: and begin at my sanctuary."

Dioscorides (B. C. 40-30), physician to Antony and Cleopatra, in a dissertation on the medicinal herbs, gives the proportion of lampblack and oil to be used in the manufacture of ink.

Vitruvius (B. C. 30-A. D. 14), the Roman Engineer, describes a method of preparing ink for mural decoration:—soot from pitch pine being collected from the walls of a specially constructed chamber, then mixed with gum and dried in the sun.

Pliny, the Elder (A. D. 23-79), mentions that writing could be removed by means of a wet sponge. Martial (A. D. 100), a Roman Poet, sent a sponge with his newly written book of poems, so that

the writing could be effaced if the composition did not merit approval. Although the Romans used an oil carbon ink, the last two references must either refer to a lampblack (carbon) gum ink or to a sepia ink for the oil carbon preparation could not have been removed by sponging with water.

PINK INK

Somewhere between the civilization of Egypt and the "Grandeur that was Rome" the art of producing chemical writing fluid was lost, the Romans did not use them but as recorded by Cicero, depended upon the rich brown excretion of the cuttle fish for their writing fluid. It was not until about 200 A. D. that the employment of ink again became popular. Red inks, blue inks and inks of Tyrian purple were used.

The transition from carbon inks to iron gall inks which are the ordinary blue black writing fluids of today took place gradually from the tenth to the twelfth century. About the same time the introduction of flax or linen paper provided a suitable material to be used with the inks. Iron gall inks probably came into use at a comparatively early date in Ancient Syria because of the proximity of the most important raw materials, the gall nuts and the iron sulphate. The high state of civilization which flourished ages ago in Asia Minor was probably due to the use of ink by which a flexible means of communication and recording was made possible.

IRON INK

The monk Theophilus, who wrote an encyclopedia of Christian Art in the eleventh century describes among other things, a method of preparing ink for writing from thorn wood (tannin bearing bark). An aqueous extract of the wood was evaporated to dryness and the powder mixed with green vitriol (iron sulphate). This is the earliest reference which has been found to an iron tannin ink.

Albertus Magnus (A. D. 1193-1280) also refers to the preparation of an ink from green vitriol in his treatise De Rebus Metallicis.

The first manufacturer of inks of whom we have any record was a Frenchman, M. Guyot, who made and sold ink in Paris in 1609. William Lewis, an English Physician, in 1748, has the credit of being the first to make writing fluids the subject of scientific experiments and to draw conclusions as to the proportions of the various ingredients required to make a really permanent ink. In 1890

Schluttig and Neumann, after extensive investigations, published a formula which they believed would give the best possible iron gallotannate ink. This ink was adopted by the State of Massachusetts as the standard for all official purposes. In 1912 the Prussian Government issued regulations requiring that documentary or record inks should meet certain standard specifications. The United States Government incorporated in its specification for "Treasury Standard" writing fluid the requirement that ink furnished should be equal in every essential to a standard ink made according to the formula adopted by the State of Massachusetts.

STANDARD INK

Thus, it can be seen from this short history of ink that no standard ink was required for recording purposes until 1890 or later which was indeed unfortunate because wills, deeds, birth certificates and the like should be written with ink that is as lasting as the paper they are written on.

Ancient inks were of many varieties, the earliest writing inks were composed of lampblack or other form of carbon in admixture with a glue or gum, and were prepared for use by rubbing on a palette with water. The Persians used an ink which was made by roasting date stones in a stoppered earthenware vessel, then grinding and sifting the contents and making into a mixture with gum arabic and water. This Persian ink probably contained very little carbon but most likely contained black organic compounds of a tar-like nature.

ROYAL INK

The inks of Tyrian purple previously mentioned were made from the secretion found in a small cyst, adjacent to the heads of certain of the Murex, a kind of mollusk. This deep crimson dye was possibly the first to be used in dyeing wool or linen. It was an extremely costly dye and the phrase "to be born in the purple" refers to the fact that a child had to have parents of considerable wealth to see the light of day in a room decorated with drapings dyed with Tyrian purple. Pliny the Younger (A. D. 61-115), stated that Tyrian purple cost $150 a pound.

Sepia which Cicero wrote about was also of animal origin. This black or dark brown pigment is contained in a secretion formed in a special glandular organ of the cuttle fish or squid (Sepia officinalis). Sepia as a natural ink antedates every other ink in the world, artificial or otherwise. It has great pigment value, one part of sepia imme-

diately renders one thousand parts of water opaque. It is the most lasting ink of all natural substances.

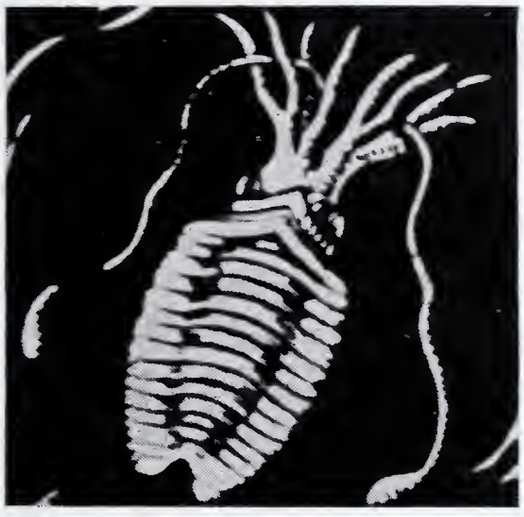

Fig. 1.

The Cuttle Fish (Sepia Officinalis) or Squid Has a Special Glandular Organ From Which a Pigment Is Obtained Used in Making Sepia Inks.

In the middle ages both the carbon inks and the iron gall (iron tannin) inks appear have been in common use, although it is thought that the iron gall inks were most generally used as the secret of making a satisfactory carbon ink was gradually lost. The iron gall inks from the eleventh century until about 1856, were known as oxidized inks while our modern iron gall (blue black) inks are unoxidized.

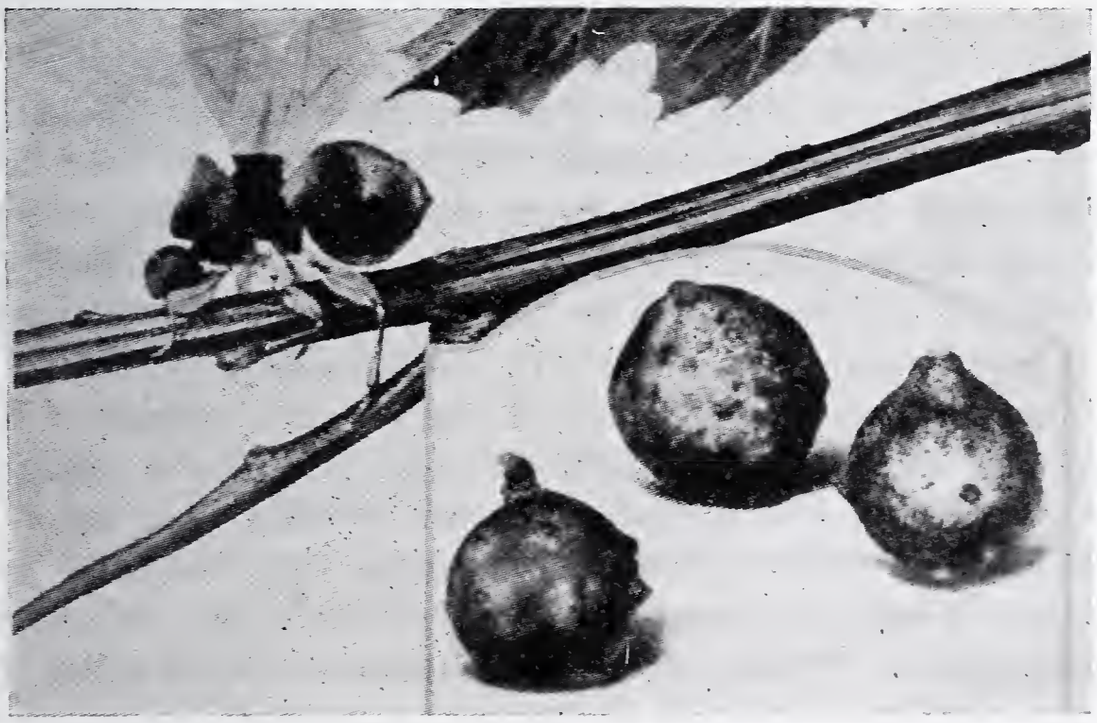

Fig. 2.

Mrs. Cynips Gallae Tinctoria, the Gall Fly Which Causes the Formation of the Nut Galls (Lower Right) From Which Tannic and Gallic Acids Are Obtained.

The oxidized inks were so-called because they were made by mixing the gall (tannin) extract with the iron sulphate (Copperas) and gum, leaving the liquid exposed to the air until it had yielded a mixture of colloidal and insoluble iron tannates which remained more or less in suspension in the liquid. This type of ink was poor for writing purposes for the ink was practically all on the surface of the paper, no penetration taking place because the iron tannates were precipitated before the ink was used whereas to have a penetrating action into the fiber, to make the writing more nearly permanent, the ink should oxidize after coming in contact with the paper.

The modern inks are legion, there is an ink for practically every purpose. The inks which are the most interesting to read about and the most widely used by all of us are the writing inks. Writing inks are fluid substances containing coloring matter either in solution or suspension and commonly in both conditions that can be used with a pen to mark letters, characters or other designs on any surface prepared to receive it. They may contain any pigment which can be dissolved or suspended in a suitable medium. Inks may be classified roughly into five classes: aniline inks, logwood inks, nut gall inks and miscellaneous inks such as invisible inks, etc.

COAL-TAR INKS

Aniline inks are fluids made by dissolving aniline dyes or as they are often called, coal tar dyes, in distilled water and adding a preservative such as carbolic acid (phenol) or thymol to prevent the formation of mold growths. An ink of this type can readily be made by dissolving 5.5 gm. (about one-fifth of an ounce avoirdupois) of the dyestuff in 1000 cc. of distilled water. For ordinary writing purposes these inks were very satisfactory because they contain no acid which will corrode steel pens but they are "washable" or "fugitive" and writing done with them is easily smeared or removed by the application of water. The word "washable" is misleading for it really means, capable of being washed without damage to fabric or color but as was mentioned before "washable" inks cannot be washed without smearing or removing the color although the manufacturer may mean to imply that it can be easily removed from fabric and the like, in case it is accidently spilled. When writing is done with this class of ink there is no chemical action with the paper but only a deposition of the dye as the water evaporates. Of interest in connection with the use of aniline inks was a case in which the Fiji Islanders were con-

cerned. One ink manufacturer was surprised at the amount of blue ink which the Islanders used, so a curious salesman of the firm wondering if it could be due to a sudden advance of learning, decided to stop and look into the matter. To his surprise he found that the aniline ink was used by the natives to dye their straw hats a striking blue color.

SOOT INKS

Carbon inks, known commonly as China and India inks are both essentially made of very finely powdered particles of lampblack, a form of carbon, held together by some kind of glue. The China ink used mainly in China is manufactured in the form of sticks or cakes which are rubbed down in water for use with small brushes instead of pens. India ink is procurable in liquid form and is made by mixing gum arabic, shellac, and borax, with carbon in suspension. Camphor is sometimes an ingredient of India ink, also. The borax reacts with shellac to form a kind of soap which is soluble in water, but which after drying forms an insoluble film on the paper. The gum arabic is thought to act as an aid to hold the carbon in suspension. Some brands of India inks are manufactured for ordinary writing purposes but their widest application is as drawing inks, used by architects, engineers and artists, to whom their intense blackness overbalances their fast drying properties and their heavy sluggish flow. These drawbacks prevent their more extensive use as ordinary writing inks.

Carbon inks should be used on paper which is just slightly absorbent for this type of ink has the coloring matter in suspension and the color will not impregnate the fibre unless the paper is sufficiently absorbent. Writing done on a nonabsorbent surface will chip off when dry or it can be mechanically removed. These inks are very permanent when used on slightly absorbent materials, for light and chemicals do not affect them.

LOGWOOD INKS

Logwood inks are made from extract of logwood, crystallized sodium carbonate and potassium chromate. Logwood is the heartwood of a tree scientifically called, Haematoxylon campecheanum. The tree is a native of Central America and has also been introduced into the West Indies. The heartwood which is usually marketed in small chips is put through a process very much resembling the steeping of tea in order to extract the coloring matter. The inks write a purplish black and dry readily

forming an intense black into as well as onto the paper. The writing can be freely washed without danger of smudging, but it decomposes upon ordinary exposure to air, the deposit chipping off of the paper in small flakes.

The common blue black inks are nutgall (iron tannin) inks. The base ingredients of these inks are tannic and gallic acids, two extracts of the nutgall, and ferrous sulphate, commonly called copperas or green vitriol. These chemicals form a nearly colorless solution which will darken by oxidation upon exposure to air. This colorless liquid on coming in contact with paper, reacts with the fibers of the paper forming a black iron compound in the fibers, so that writing remains as long as the paper it is written on lasts. However, the colorless liquid just mentioned could not be used for writing because the writing would be practically invisible at first. For this reason a blue dye such as indigo or a water soluble blue aniline dye is added, then on writing, the words are blue and in time the blue fades and black predominates because of the formation of ferric salts due to the oxidation of the ferrous tannate and gallate. Thus, blue black inks are those which write blue and turn black.

Nutgall inks are quite permanent and are recommended by the leading ink manufacturers as not only the best but the only record ink for commercial and documentary purposes. It is not surprising, therefore, that the branches of the Federal Government and those states requiring the use of an official ink recognize and designate nutgall inks as best for all enduring records.

INK RIVER

Iron tannin inks are sometimes formed naturally, such a phenomenon has been observed in Algeria, a country in northern Africa, where there exists a "river of ink." Chemical examinations of the waters of the streams combining to form this river revealed that one of the streams is impregnated with iron from the soil through which it flows while the other stream carries tannin from a peat swamp. When the two streams joined, the chemical action between the tannic acid, the iron and the oxygen of the water caused the formation of the black ferric tannate, making a natural river of ink.

However, man does not depend on nature's ink well but manufactures large quantities of nutgall ink from materials gathered from different parts of the globe. The process of manufacture begins with the extraction of the tannic and gallic acids from the nutgalls, ab-

normal growths of the oak tree, the Quercus infectoria, which grows abundantly in Syria, Asia Minor. The nutgalls from this source are the Aleppo galls which yield the best tannic acid for the manufacture of inks. Centuries ago, inks were made directly from the extracts of the galls, but today, the control chemist uses exact amounts of gallic and tannic acids with the result that a uniform ink is produced. Tannic and gallic acids in solution in contact with air gradually turn a light brown and in combination with a mineral salt, such as ferrous sulphate, turn a deep black color. In time a black precipitate forms which is soluble in acid so the ink manufacturer adds sulphuric or hydrochloric acid to the ferrous sulphate solution before the tannic-gallic acid solution is added to prevent any precipitation which might be produced such as exposure to air in an open ink well. It is obvious that a solution used for writing would penetrate the fibers much more readily than a liquid with insoluble material present, therefore a solution is to be desired so that a more nearly permanent record would be obtained and also for fountain pen use where insoluble material would clog the pen. In addition to the ingredients just mentioned, carbolic acid (phenol) is used in the inks to eliminate the possibility of moulding.

NUTGALL INK

Nutgall ink is a fairly permanent type of ink withstanding the ravages of time, sun, wind and rain. One of the large ink manufacturers of this country has a page from a handwritten book, dated 1445 and the writing, which was done with nutgall ink, is as clear and black as the day it was written. In the great Baltimore fire of 1904, J. S. McDonald Company, jewelers, were burned out and their books lay in water for a week. On recovery, the writings were found perfectly legible. Similar cases are on record where sudden floods and other catastrophes would have meant ruin to firms' books and records, had they not been safeguarded with this permanent ink.

SECRET INKS

A consideration of miscellaneous inks leads first to an interesting type, the "so-called" secret, "sympathetic" or invisible ink. This kind of ink is used in peace times for confidential correspondence and in war times for secret messages. A host of different materials can be used to make up an invisible ink. During the Indian Mutiny of 1857 rice starch was used, writing with this ink being developed by means of iodine. Some of the materials used during the World War were substances of everyday use

which could be bought openly and others were uncommon organic compounds. The common sympathetic ink is one made from cobalt chloride. A weak solution is used for writing, which drys a pale pink and the writing when warmed changes to a distinct blue which is easy to read. A solution of phenolphthalein can be used as an invisible ink, the writing being made visible by exposing to ammonia vapors. Onion juice or milk can be used, the writing being made visible by heating just enough to scorch the dried juice or milk.

Another type of miscellaneous inks is the typewriter ribbon inks. A form of typewriter was patented in England in 1714 but it was not until 1873, after a series of developments, that the device was fairly complete for practical use. The inked ribbon had to be produced as a very important part of the machine and today, the manufacture of typewriter ribbons is an industry in itself. The base of the inks used for record ribbons is usually a slow drying oil like castor oil mixed with oleic acid. The oil soluble coloring matter is ground in a mill with the oleic acid and the mixture incorporated in the oil. The ribbon to be inked is passed through rollers, set at a definite distance apart, between which the ink is fed from a reservoir adjoining the rolls. The two-color ribbons such as the red-black ribbons are inked in one operation by passing through rollers which are fed by ink from two reservoirs. A partition at the rollers prevents the black ink from mixing with the red ink or vice versa. The finished ribbon has an uninked line the size of the partition directly in the center into which the inks work from both sides until it is entirely inked.

Care must be taken that the fluidity or viscosity of the two inks is the same so that one color will not bleed into the other as the ribbon is inked. While using a typewriter one may notice that the written words are not so plainly impressed on the paper toward the end of a long letter as they were in the first part of the message, this occurs because the ink has been used up to some extent from that portion of the ribbon which has been in use continuously. If the typewriter is not used for about an hour, ink from the unused part of the ribbon will flow into the used part showing a good "recovery" which in turn shows a well-inked ribbon.

PRINTERS' INK

Printers' inks which have been used ever since the invention of the printing press about 400 years ago, have as their main pigment, carbon. Lampblack, a form of carbon,

made by burning rosin, turpentine, pitch, and petroleum oils, was used in the first printing inks until 1864. At that time, carbon black, made by burning natural gas, by a certain process, was introduced and at the present time it is the indispensable material used in a finely divided condition in printing inks. Lampblack is still used to a limited extent, generally mixed with a certain proportion of carbon black. The inks are made by mixing the pigments in boiled drying oils, such as linseed and tung together with driers such as lead, cobalt and manganese in the form of their resinates or linoleates. Other ingredients such as varnishes, mineral oils and petrolatum may be added in making inks for particular kinds of printing work. Nine pounds of ink containing one pound of carbon black and eight pounds of oil and other materials will print ninety copies of a three hundred page octavo book. News inks are made by mixing carbon black and mineral oil in the approximate proportion of one pound of carbon black to eight or nine pounds of oil. This nine to ten pounds of ink will print twenty thousand pages of the average newspaper size.

A knowledge of inks is often valuable in deciding whether documents such as wills, deeds, and similar official records are authentic or not. In one case, it was alleged that the writing on a document was written in 1868. On examination of the red ink used, it proved to be one made from the synthetic dye eosin, which was not discovered until 1874 and not used in inks until several years later, which showed the writing to be fraudulent. In another case of a will which was altered by writing over the original writing, it was found by treatment with the proper chemicals that the two different inks, used for writing over the top of the original ink, could be dissolved, exposing once again the message which the rightful testator had written. Sometimes documents are found on which the writing has faded out from age. This writing may in some cases be restored by the use of the proper chemicals. There is little hope of restoring writing made with inks that are solutions of dyes, because practically nothing is left on the paper when the color has disappeared. If the ink contained iron tannate (blue black ink), there will always be some brown oxide of iron left on the fibers of the paper, and this can be changed into a more intensely colored iron compound. The simplest treatment is to expose the paper to the fumes of ammonium sulphide, which will change the iron oxide into black iron sulphide. Another method is to apply a solution of tannin, which will form black iron tannate.

When it was decided to exhibit the Declaration of Independence in the Library of Congress, the suggestion was made that the writing should be restored with chemicals. Owing to the danger of damaging the document irreparably during the treatment, and because of the possible after-effects of the chemicals upon the paper this was not done. Thus, we see it may or may not be wise to restore faded writing.

THE NATION'S INK BILL

The nation's ink bill is considerable. It has been estimated that there has been three to four million dollars' worth of writing ink used during the past year in the United States. If drawing, lettering and inks for similar purposes, not including printing inks, are estimated along with writing inks about six million dollars were expended during 1929. The printing ink industry is very vast, it is believed that New York City and vicinity uses ten million dollars' worth of ink annually. The total consumption of all kinds of inks probably amounts to one hundred million dollars per year.

Although one might think that the state of a nation's civilization could be judged by the amount of soap which it uses, it would seem that it might be judged even more accurately by the amount of ink used yearly in recording its accumulated knowledge.

BIBLIOGRAPHY

Carvalho: Forty Centuries of Ink.
Allen, A. H.: Commercial Organic Analysis, Ink, Ed. 4, Vols. 5 and 9.
Mitchell and Hepworth: Inks, Their Composition and Manufacture.
Scientific American Cyclopedia of Formulas.
Henley: Twentieth Century Book of Recipes, Formulas and Processes.
Lucas: Forensic Chemistry.
Mantell: Industrial Carbon.
Bureau of Standards Circular No. 95.

SOUND PRODUCTION AND REPRODUCTION

By George Rosengarten, Ph. D.

THIS IS the Talking Age. You ask "What makes the Movies talk?" or "How does the Radio speak?" and to these questions I shall attempt an answer. The past generation gained their information from the pages of the press or in the peace and quiet of the home read the best of books. Today the plot must be put upon the screen with the synchronization of sight and sound. We have broadcast at us the sound from the shop windows, we eat and try to sleep amid these sound waves. One need not attend Church or the Prize Fight to be uplifted; tune in some distant station to your pleasure.

George Rosengarten

Man's progress is very closely related to the tools with which he works. The Scientist employs most remarkable tools to accomplish his desires; the Vacuum Tube and the Photo-Electric Cell have performed these modern miracles. No one can claim to have invented the Radio or the Talking Pictures as we know them today for they are the result of years of research on the part of scores of Scientists into the nature of Sound Production and Reproduction.

What is the nature of sound? It may be the buzzing of an insect or the roar of the subway; the sweet voice of a beautiful soprano accompanied by the artist on the piano or the sound of distant thunder. In every case where a sound is produced one is certain to find a vibrating mass of matter. The insect by beating its wings, the wheels of the train by pounding on the rails cause a vibration. The vocal cords are forced to vibrate by the exhaled air, the strings on the piano are set into vibration by the blow of the hammer and the flash of lightning has produced a sudden expansion of the air.

If I set the prongs of a tuning fork into vibration the motion will be transmitted to the surrounding medium in which a vibration is set up corresponding to the vibration of the tuning fork. This motion of the medium takes the form of a wave about the vibrating body as a center and extends in all direction as a spherical disturbance ever in-

creasing in size until dissipated by friction among the particles of the medium. This is fortunate, otherwise a vibration once established in the medium would continue without loss of energy and this planet would not be a place on which to live. When these waves strike the ear drum there is produced the sensation of sound, but we must not suppose that in the absence of an ear no sound would be produced.

Sound Defined

The physicist defines sound as the disturbance produced in the surrounding medium by the vibrating body. This disturbance travels as a wave for some distance from the source and may be detected by an ear or some other delicate receiver.

In order to understand the phenomena of sound production or reproduction we must study the characteristics of a vibrating body. A stick clamped at one end and disturbed at the other end will be set into vibration and produce in the medium a disturbance of sufficiently high frequency to produce the sensation of sound. Sounds may have a frequency too low or too high to produce audible sound since the human ear has a lower limit of audibility of about 20 vibrations per second and an upper limit of about 30,000 vibrations per second.

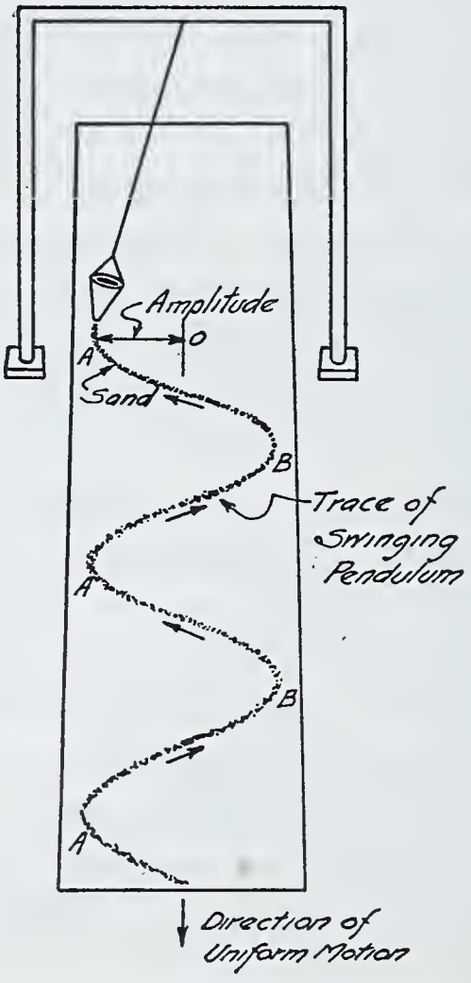

Fig. 1. Swinging Pendulum.

A swinging pendulum executes a vibration which has all the characteristics of the vibrating stick and for my purpose may be made to produce a visible graph of the peculiarities of a vibration.

By allowing sand from a cup swinging as a pendulum to trace its motion on a strip of paper moving uniformly along the top of the table we produce a wavy line which may be studied. The maximum distance OA from the position of rest to which the vibrating body is displaced is called the amplitude of the vibration and is a measure of the intensity of the disturbance produced. Such a body if elastic continues to vibrate for some time and the number of excursions from A to B and back to A which take place in a second is the frequency of the vibration. If the frequency is large the note produced will have a high pitch while a low note is produced by a body which makes fewer vibrations per second. In this way I have defined several of the terms which I shall use in our study of sound.

If I strike the table I produce a vibration in the surrounding medium, perhaps not very pleasing to the ear, but since the table has a larger area than the fork the disturbance produced by the table will be greater. This can be shown by using some form of sounding board in connection with the fork which will increase the magnitude of the sound produced by the fork acting like a kind of loud speaker.

The mechanism by which such a disturbance is transferred to the ear is very similar to the wavelets which are produced when a stone is thrown into the water. A series of concentric circular ripples are produced upon the surface of the water which increase in size and disappear in the distance. The disturbance produced by the vibrating body travels through the air in all directions as a series of spherical shells of increasing radius finally fading because of friction between the molecules of the air.

Such a disturbance on the water surface or in the air is called a wave in which the characteristic displacement of the particles of the medium repeats itself at frequent intervals. In the water wave the particles move up and down about the position of rest and communicate such motion to the adjoining particles producing the illusion of motion of the water from the source of the disturbance. A rope or coiled spring fastened at one end and held in the hand at the other end may be used to show such a wave. A motion of the hand, up and down, will produce a disturbance which will travel along the rope, but it is certain that the particles of the rope have not moved forward.

In a similar manner the disturbance produced by the vibrating body causes the particles of the air to move back and forth over rather short distances communicating such motion to the neighboring particles, the entire disturbance travelling forward as a sound wave and continuing for some time before losing all of its energy.

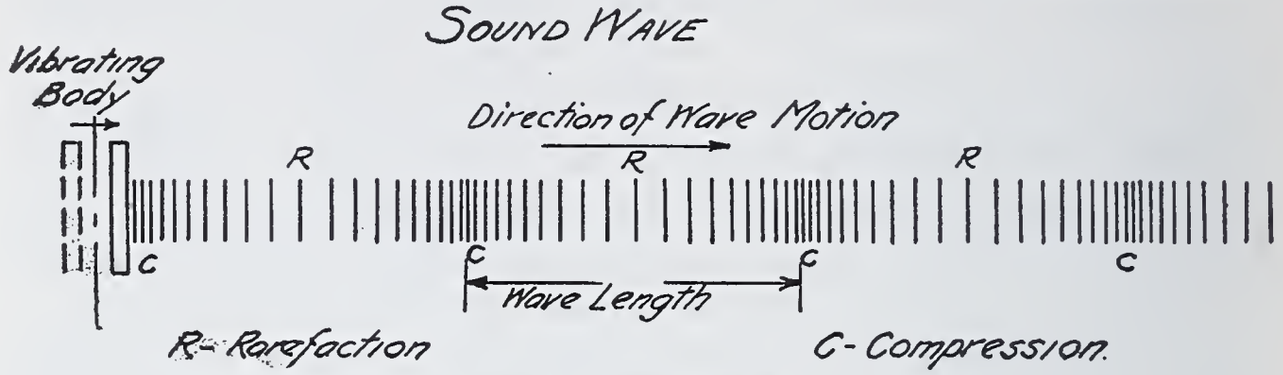

Fig. 2. Sound Wave.

Let us examine minutely the motion of the particles of the air in a sound wave. As the vibrating body moves from A to O to B the particles of the medium will be pushed forward causing a region of compression. Upon the return of the vibrating body from B to O the elasticity of the medium will cause the particles to return to their normal position, but since the vibrating body continues to move beyond its normal position to the point A the particles of the medium will follow after causing the pressure in the medium to be reduced below the normal pressure producing a region of rarefaction. The repetition of the motion of the vibrating body will cause a second increase in pressure followed by a corresponding reduction, thereby setting up a disturbance in the medium which travels as a sound wave with a speed of about 1100 feet per second.

Sensation of Sound

When this disturbance reaches the ear there is produced the sensation of sound. The ear is the most universal receiver of sound, capable of detecting vibrations whose amplitude varies from 1/100,000,000 centimeter to 1/100 centimeter and of frequences from 20 to 30,000 per second.

This makes it necessary to examine the nature of the structure of the ear. Three separate compartments exist in the ear, each separated from the other by a stretched membrane. The outer ear assists in collecting the sound wave and conducting the disturbance to the ear drum or tympanic membrane which closes the middle ear. In most men the external portion of the ear lies so close to the head that it no

longer serves this purpose and can be greatly assisted in the reception of feeble sounds by holding a cupped hand to the ear.

In the middle ear is located a combination of levers consisting of the three smallest bones in the body, called the hammer, anvil, and the stirrup. They are connected to diaphragms at both ends of the middle ear and communicate the vibrations from the tympanic membrane to the small oval window which opens into the inner ear. This window is covered by a membrane to which the stirrup is attached and also serves to prevent the loss of the fluid which fills the spiral cavity of the inner ear. The vibrations of the air are communicated by the bones of the middle ear to this fluid contained in the inner ear with considerable increase in pressure. The stress thus produced upon this fluid acts upon certain nerve fibers communicating with the brain.

Man has from early times invented instruments which produce musical sounds. Among the instruments for the production of sound the human voice must be considered. The new born infant by forcing the air in its lungs through a slit formed by a pair of muscles in the larynx can produce disturbances which bring results of one kind or another. Early forms of language were little more than grunts which in time became modulated or changed in character by the relative position of the mouth and lips. Musical instruments have been designed which depend upon the vibration of a string, a column of air, or a stretched membrane.

The character of the Sound Wave produced by the different instruments has been made visible by numerous pieces of apparatus employing the same principle as the ear. The disturbance produced by the vibrating body falls upon a diaphragm which is caused to vibrate with the same frequency as the sound. By reflecting a beam of light from a small mirror attached to the diaphragm the peculiarities of the sounds may be studied.

The vibration of a tuning fork produces a pure tone. A photographic record (Fig. 3) of the sound of the vibrating fork looks like the trace produced by the swinging pendulum and in fact is produced by a very similar motion. Such a motion is called a Simple Harmonic Motion. A tuning fork which makes 256 vibrations per second communicates to the medium and to the ear drum 256 changes in pressure per second represented by the loops shown in the graph.

When the same note is produced upon different instruments and the sound analyzed we observe in addition to the fundamental frequency the existence of other frequencies superimposed upon the

fundamental having frequencies 2, 3, 4, etc., times the frequency of the fundamental. The number and the relative intensity of these so-called harmonics gives to each musical instrument the peculiar quality of its tone.

Speech frequencies range from 200 to 6000 per second. Each vowel sound gives rise to a different form of graph and the character of the disturbance produced when a vocal selection is rendered by a quartet is very complex.

In addition to these musical sounds which have a definite frequency there are many other sounds such as one hears in the subway

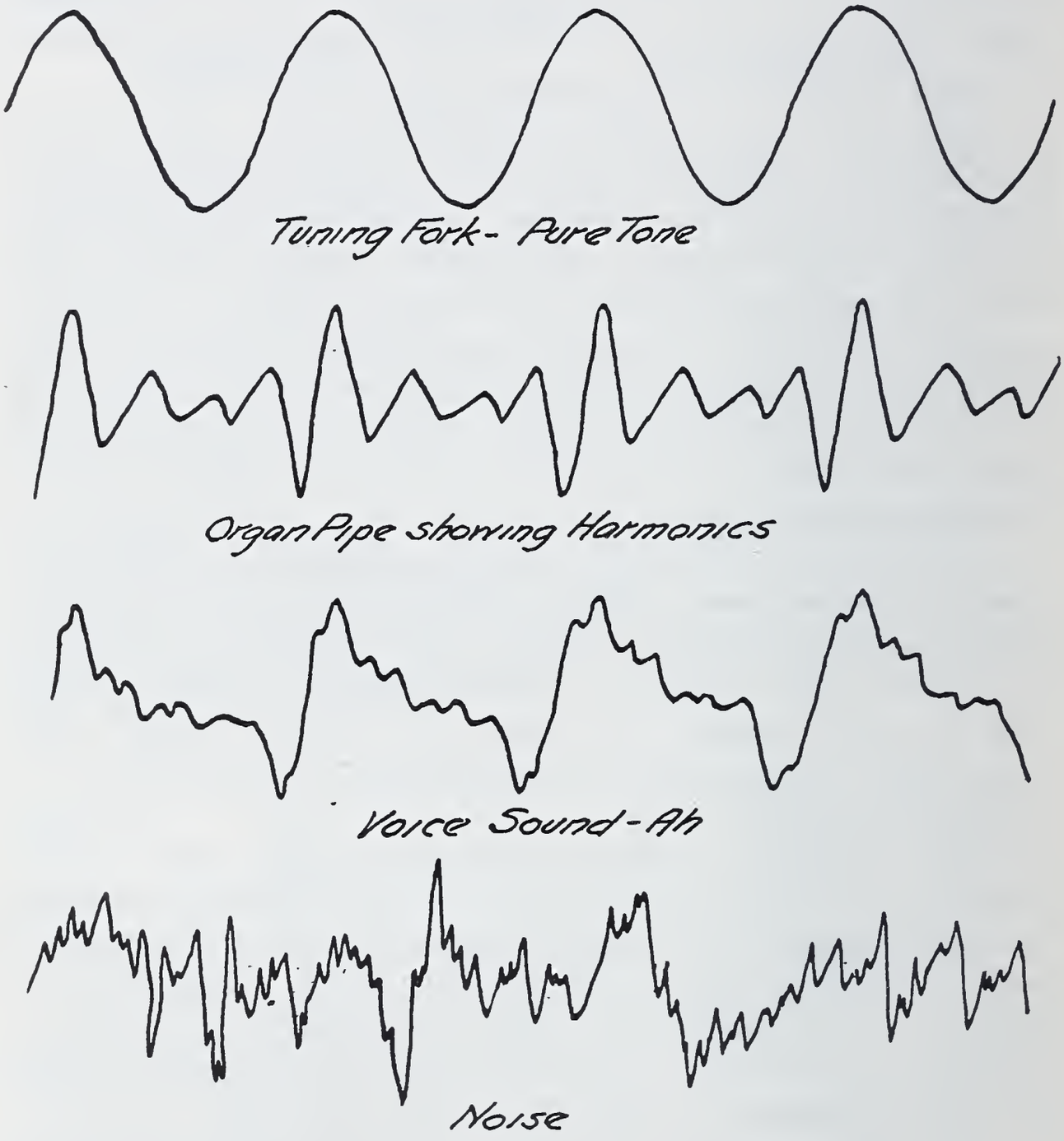

Fig. 3.

or on a busy street which are classed as noise because they have no particular frequency.

Modern civilization requires that we be able to communicate with one another by word of mouth no matter what the circumstances. We may be riding in an express train or flying through the air or we may have journeyed to the ends of the earth; our friends must hear from us. It is this great variety of sounds of varying frequencies that we have been called upon to reproduce and you know how well we have succeeded.

It is my purpose to show in what manner and along what lines the reproduction of sound has proceeded. I have stated that wherever we have a sound produced we have a vibrating body and in order to reproduce this sound it is necessary to transmit the vibrations of the original body by mechanical or electrical means to another body which may be set into vibrations of the same frequency.

Mechanical Reproduction

There was developed as early as 1859 by Koenig and Scott an instrument called the Phonautograph which contains at least some of the ideas employed in our modern instruments. The sounds collected by a horn set in vibration a diaphragm causing a stylus to trace a curve on a piece of paper attached to a rotating drum. These curves were similar to those shown in Fig. 3. This instrument merely recorded and was unable to reproduce the sound.

It was Thomas Edison who, in 1877, conceived the idea of replacing the paper by a layer of tin foil which was indented by the stylus producing a record of the sound which could be reproduced. To reproduce this sound the stylus is again set at the beginning and by rotating the drum at the same speed the diaphragm is caused to repeat its vibrations and emit an imitation of the original sounds. The first phonograph was soon improved by the use of wax cylinders with the later development of the disc record, upon which is impressed in a spiral groove a wavy line corresponding to the variations in the original sound. In playing such a record a needle is caused to follow the wavy line and in so doing transmit through a system of levers the motion somewhat intensified to a diaphragm which is caused to reproduce the vibrations corresponding to the original sound which made the trace upon the disc record. This is purely a mechanical reproduction and is subject to the limitations imposed by the mass or inertia of the moving parts.

Electrical Reprcduction

The great discovery of Alexander Graham Bell was that of electrical reproduction when in 1876 he invented the speaking telephone. By combining the principle of the vibrating diaphragm of the Phonautograph with the electro-magnet Bell laid the foundation not only for the telephone, but also for the microphone and the loud speaker. The telephone receiver in use at the present time is not very different from the original, an electro-magnet receiving the varying current and causing the iron diaphragm to vibrate with the same frequency as the sound produced at the transmitting end.

The transmitter has undergone a greater change, since in the first telephone both the receiving and transmitting instruments were of the same construction. In the transmitter the sound waves cause the diaphragm to vibrate and produce a variation in the pressure between two carbon discs. The discs are connected in the electrical circuit and the space between them filled with carbon granules whose resistance depends upon the pressure which varies in accord with the vibrations of the sound causing similar variations in the current sent to the receiver at the other end of the circuit.

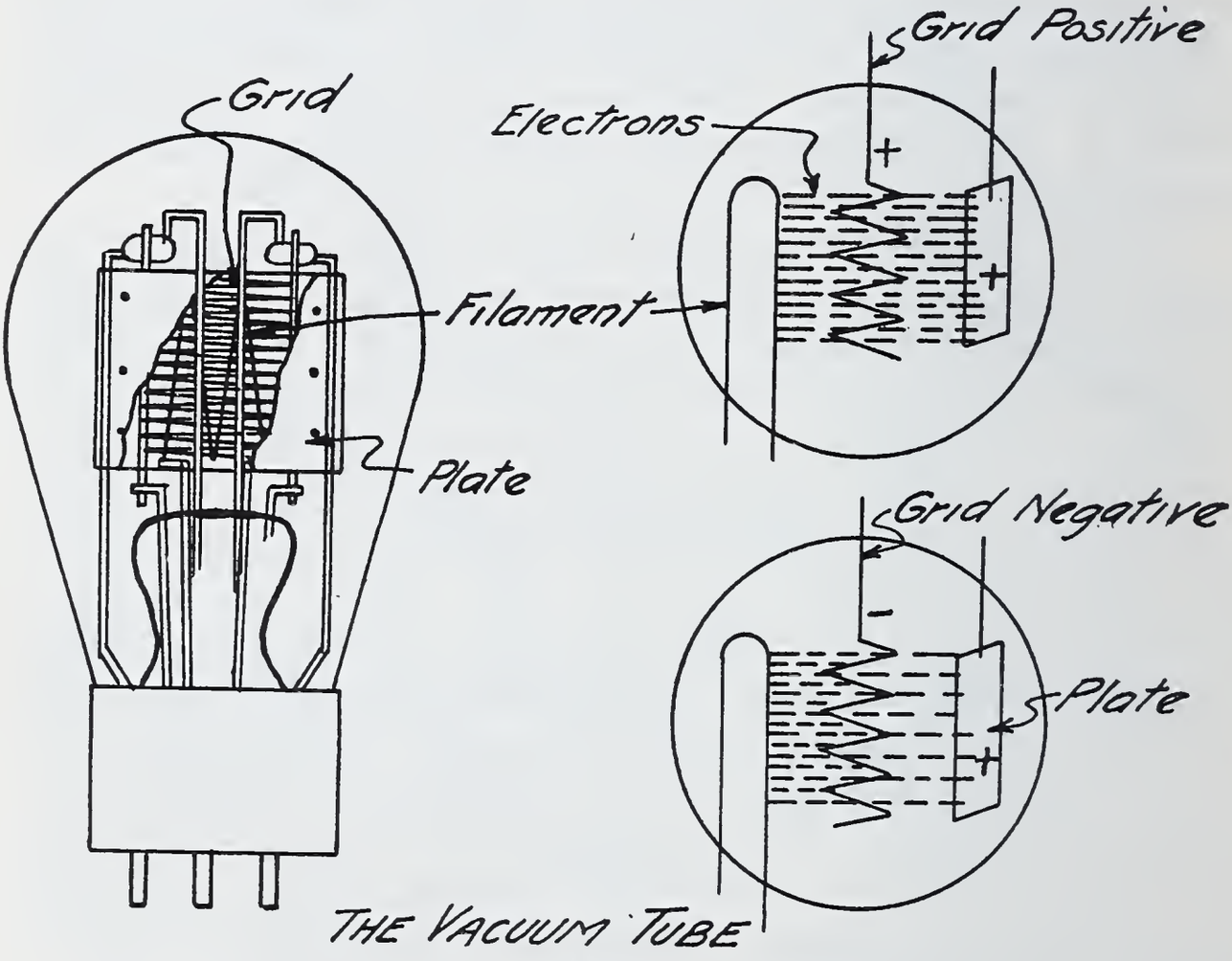

Fig. 4.

Vacuum Tubes

The big improvement in the reproduction of sound by Radio is due in great measure to the research of Flemming and DeForest in the development of the Vacuum Tube, a new scientific tool of remarkable sensitivity. The atom of matter no longer remains indivisible. Within the vacuum tube, under the influence of heat, the atom disintegrates into positive and negative electricity. It is the negative particles, the electrons, in which we are at present interested.

The elements of the vacuum tube consists of a plate, filament and grid. The heated filament resembles that of an ordinary electric lamp working at low voltage from which electrons are radiated into the surrounding vacuum. The cold plate is charged positive and therefore attracts to its surface the negative electrons completing the circuit through the vacuum from the filament to the plate. The third electrode called the grid consists of a fine network of wires between the filament and the plate and acts as a valve regulating the flow of electrons within the tube. When it is charged positive it will assist the plate in collecting the electrons and when it is charged negative it will retard the flow. It is this property of changing the flow of the current from the filament to the plate that is made use of in the radio circuit.

To transmit radio signals we must produce at the sending station an alternating current of very high frequency in the neighborhood of 1,000,000 cycles per second. This energy is radiated from the antenna as a carrier wave and travels through space at the rate of 186,000 miles per second. This high frequency carrier wave is modulated, that is, made to vary in amplitude, according to the sounds produced in the microphone. In your radio set the grid in the detector tube is connected to the antenna and receives the variations in charge caused by the modulated wave. These exceedingly feeble variations cause changes in the current from the filament to the plate of the same frequency as the sound wave produced at the microphone. The output of the detector tube is amplified by the use of several additional vacuum tubes making it possible for the current to operate a loud speaker.

Loud Speaker

The principle of the speaker is much the same as the telephone of Alexander Bell. The armature of an electro-magnet is connected by a system of levers to a diaphragm or cone which is set into vibration as the armature moves back and forth

with the changes in current flowing through the electro-magnet. Since these changes in current have the same frequency as the sound produced at the microphone the cone will vibrate with the same frequency and the sound will be reproduced at the distant point. By increasing the size of the cone and the resulting displacement, the sound has been considerably increased in volume and at the same time somewhat distorted, due to the inertia of the moving parts. The dynamic speaker, employing the principle of the electro-magnetic attraction has resulted in a further improvement in the character of the sound reproduction.

The principle of the electro-magnetic attraction may be stated as follows: In the space about a magnet a field of force exists which will attract a second magnetic field, tending to move the two magnets together with a force which varies in magnitude with the intensity of the magnetic fields. In this type of loud speaker we have a large electro-magnet producing a strong magnetic field. Fastened to the base of the cone and lying in this magnetic field we have a small cone coil which is connected in circuit with the receiving set and therefore carries an alternating current modulated by the sound signals. The changes in the current received cause a variation in the magnetic field of the cone coil which cuts across the field of the larger magnet and since the coil is free to move it will set in vibration the cone to which it is attached with the frequency of the sound signal received.

We have thus been able to cause the sound vibration in the air to act upon the diaphragm of the microphone and so modulate the high frequency carrier wave that it may cause these changes in the oscillations of the receiving set which is tuned to this frequency and thereby reproduce the sound with considerable fidelity. This in brief explains the action of the present type of Radio Reproduction of Sound which brings to our homes the voices of the great and near great, but how soon we can expect to reproduce their faces is a question which I am unable to answer. Since the vibrations which produce the sense of sight are of a magnitude of 500 million-million per second their reproduction at a distant point presents a very different problem, the problem of Television.

The synchronization of sight and sound has been accomplished in the talking pictures and I shall attempt to explain in what manner this has been made possible. Two methods are employed, the Vitaphone in which use is made of the principle of the Phonograph and the Movietone, in which the sound record is photographed directly upon

the film. In either case we generate a small electric current whose variations correspond to the variations in the original sound wave and after considerable amplification conduct this current to a loud speaker behind the screen in order to add to the illusion and make the sound appear to come from the speaker whose photograph appears upon the screen.

Vitaphone

The sound record consists of a large disc similar to the phonograph record. The stylus is made to follow the spiral track in which the variation in the original sounds is impressed as a wavy line. As the stylus vibrates back and forth it is made to cause variations in the electric circuit of the same frequency as the original sound. It is important that the film and the sound record shall be operated at the same speed so as to have perfect synchronization. To accomplish this both the film and the disc record are operated by the same mechanism.

Movietone

The sound record in this method of reproduction is placed directly upon the picture film and occupies a narrow band 1/10 inch wide near one side of the film known as the sound track. The appearance of the film along this sound track is a series of dark lines of varying density and spacing. The frequency of the note that is reproduced depends upon the spacing of these lines and their density determines the intensity of the sound. In order to transform these thousands of lines on the sound track into audible sound we make use of another scientific tool of high sensitivity, the Photo-Electric Cell.

Photo-Electric Cell

As a result of the research of Hertz in 1887, he discovered that under suitable conditions a ray of light falling upon a metal was able to eject electrons from the surface of the metal. In fact it was this peculiar property of light which caused the modification of the theory of light giving to it a corpuscular nature as well as attributing to it the characteristics of a wave. Within the photo-electric cell we have on one side a metallic coating consisting of an alloy of sodium and potassium connected to the negative end of an electric circuit while the positive end terminates in a metallic wire extending into the center of the glass bulb which has been reduced to a high vacuum.

If a ray of light enters the photo-electric cell a current is observed to flow, but ceases as soon as the light is obstructed by an

opaque object. The light falling upon the surface of the sodium-potassium alloy causes the ejection of negative electrons which are attracted by the positive charge on the wire in the center of the cell, thus completing the circuit through the vacuum. The very high sensitivity of the the cell to variations in the intensity of the light makes it a valuable tool in the hands of the scientist.

We shall see how he employs this cell to reproduce the sounds in synchronization with the moving picture film. It will be of interest to follow the diagrammatic sketch of the method of producing the sound film and again in reproducing the sound to observe how many different devices have been used in the production of the Talking Pictures. Certainly it cannot be said that any one has invented the talking pictures, credit must be given to the research of many, in particular to those scientifically trained workers in the Bell Telephone Research Laboratories.

In making the photographic record the sound wave falls upon the delicate microphone, producing a variation in the flow of an electric current of the same frequency as the sound. After considerable amplification the current is used to control the brightness of a lamp or operate a light valve behind which the moving film passes. The light valve consists of a shutter which opens and closes with the same

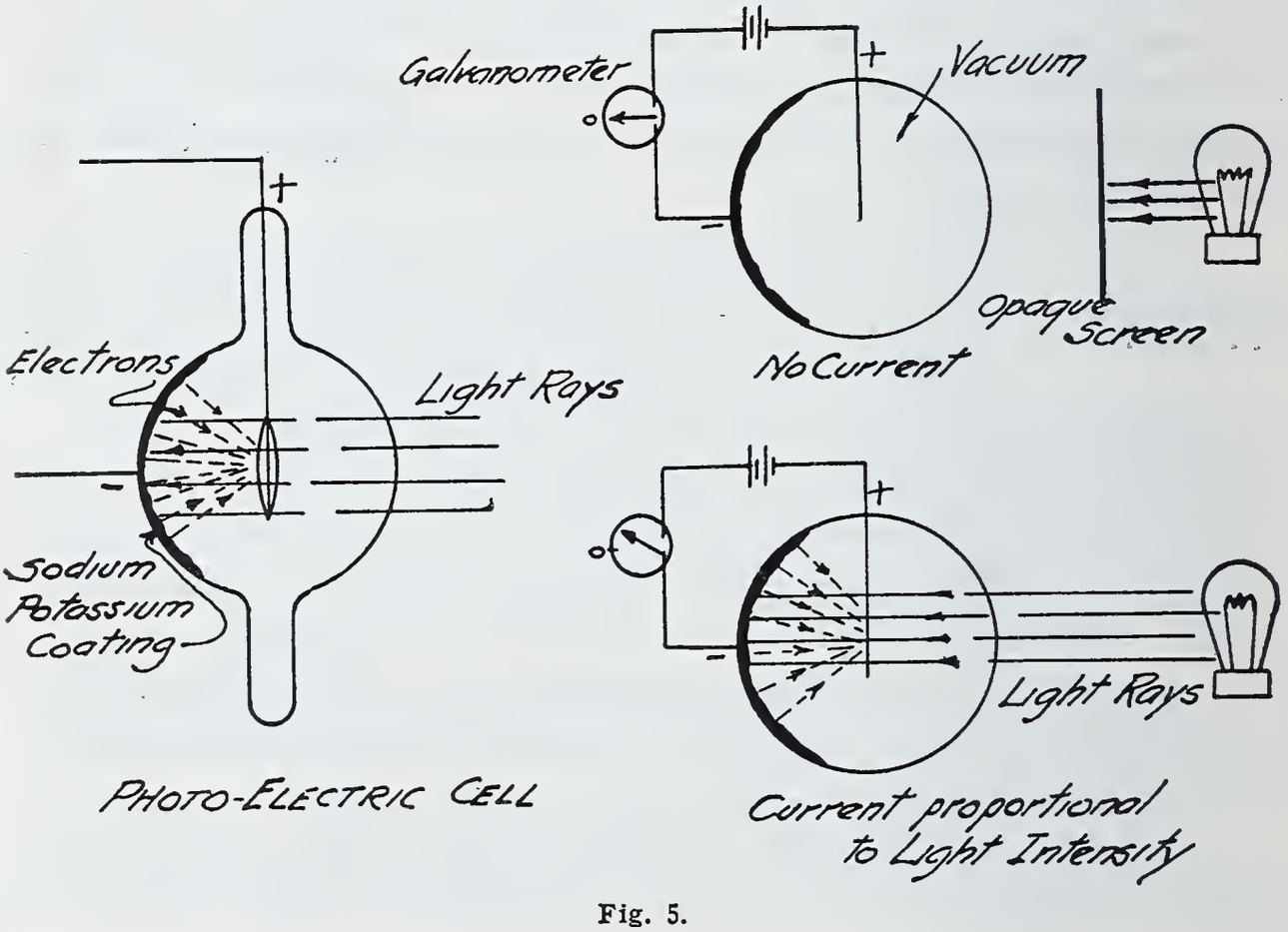

Fig. 5.

frequency as the vibrations in the sound. In either case a series of lines of variable density and spacing will be recorded upon the film.

To reproduce the sound the process is reversed, the light is caused to pass through the moving film and varies in intensity according to the variation in the density of the lines upon the film. A photo-electric cell receives the light that has passed through the film and as previously explained will produce a variation in the electric current through the cell similar to the variation in the density of the lines upon the film. This weak current from the photo-electric cell is amplified by one or more vacuum tubes similar to those used in your radio set without changing the character of the variations. By connecting this amplified current to a loud speaker behind the screen we are able to reproduce the sounds synchronized with the picture upon the screen.

I have in this brief time recalled the history of the past fifty years of progress in the Science of Sound Production and Reproduction. Many of the facts have received only a word, but I hope enough has been given to unravel the mysteries of the Radio and the Talking Pictures.

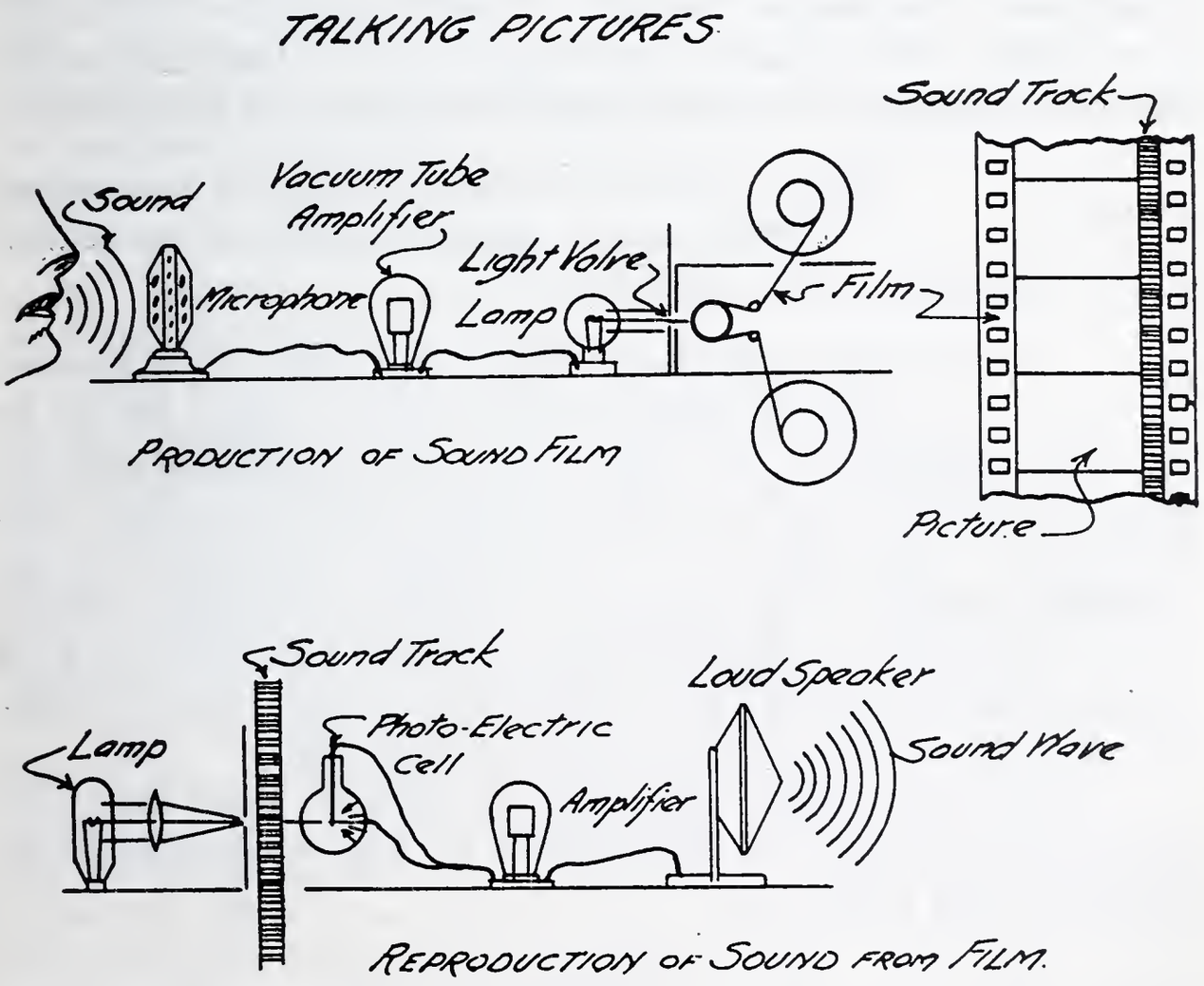

Fig. 6.

VENTILATION AND COMFORT*

By Professor David Wilbur Horn

WHEN THE SUBJECT of a popular lecture is as familiar as this one, there is small need for apologies for the absence of experiments and demonstrations. All that we shall deal with will be easily imagined by you in forms built up largely by drawing from your own experience.

Ventilation is derived from a Latin word meaning *wind*. Moving or re-moving air is the essence of our systems of ventilation. Figuratively we speak of ventilating some subject by "exposing it to the winds of public criticism." As used today the word *ventilation* includes also the factors of temperature and humidity, for these have established themselves in our experience as more or less concerned in the comfort and discomfort determined by ventilation.

TO TEMPER

To *temper* is to reduce in violence of intensity, and in this way to render less uncomfortable. The idea in the minds of most of us is well expressed in the familiar line from Stern's "Sentimental Journey"; "God tempers the wind to the shorn lamb". More exactly, "the temperature of a body may be defined as that property of the body which determines the flow of heat".

HUMIDITY

Humid is derived directly from a word that means, to be moist ,and it with its derivatives are seldom if ever used in any other connection.

GAS

Man must have learned very early the imperative need for moving away from his vicinity the air he had been breathing, for we know of no written record of this important discovery. But his ideas upon this subject must have been very hazy. Until as late as the 16th century, air was air, an imponderable element. The conception of different airs, each a distinct material, came only as the consequence of exact experiment, and led to the coining of the word *gas* by Van Helmont (1577-1644). Today everybody knows that air is a mixture of many gases.

In that age of rapidly developing knowledge of gases and of air, how natural to look in this new direction for some explanation of the difficulties with indoor air.

The fact that man had invented and developed windows shortly after he had roofed his houses may be an expression of his belief that there was something in rebreathed indoor air that ought to be let out, or that unbreathed outdoor air ought to be let in. There can be little doubt from the descriptions of the modes of living of the middle ages, that odors and man's sense of smell played an important rôle, and dictated to some extent his views on the matter of rebreathed air *versus* fresh air.

With this mediæval setting, it was logical to search for some gas in open air that was not to be found to the same extent in rebreathed air. Nor could it have caused much surprise when, after the first recognition of the gas later to be called oxygen, another investigator announced that expired air contained considerable amounts of a gas, found in the open air only in minute quantities,—later called carbon dioxide. As time passed, this substance so characteristic of expired air was shown to cause the death of animals placed in it, and it was shown that air deprived of oxygen also produced the same deadly effects. With man's experiences with rebreathed air, and with these scientific discoveries about air as premises, the syllogism was soon completed: the ill effects of rebreathed air were due to the diminished oxygen or the increased carbon dioxide, or both. And the problem was laid aside as solved, not alone for that day but solved for all time.

This was clear reasoning and was better than no reasoning at all. But very clear reasoning may be very misleading. Logic is not truthful. There are experimental ways to demonstrate the truth.

With respect to vitiated air, the first line of invincible argument against the accepted theory was chemical and physiological. Experiment demonstrated that when the oxygen in air is reduced to the lowest limit found in closed, crowded rooms, the hæmoglobin of the arterial blood is still *saturated* with oxygen. As a result of the chemical affinity of hæmoglobin for oxygen, the blood cells may still take up practically their full capacity, even when the oxygen is reduced to 12 per cent. Pure air contains about 21 per cent. of oxygen, air from the closest halls, crowded with people, seldom falls below 20 per cent. in oxygen content. It is a fact that nature does not take full advantage herself of this wide limit of 8 per cent. to 9 per cent. of oxygen. Instead she allows man a wide factor of safety, for alveolar air contains only about 16 per cent. of oxygen. In other words, as to oxygen, the air within the lungs is maintained normally at a percentage at least

4 per cent. lower than that of the most vitiated air of any ordinary place, and 4 per cent. higher than is absolutely necessary in order to supply the blood with all the oxygen it needs. Further, neither a deficiency nor a surplus of oxygen in the air, unless extreme, has any effect whatever upon the respiratory movements. Therefore, the reduced oxygen content of expired air cannot be the cause of its ill effects.

The increased carbon dioxide content of rebreathed air remains to be considered. The facts here are much as follows: At each breath we take back into the lungs expired air which has come to rest in the nose and larger bronchii—the so-called "dead-space air." This dead space air equals about one-third of a quiet inspiration. The air of the lungs is therefore very impure, and never even remotely approaches pure air in composition. Nature seems especially to have provided that pure air never should enter the air cells of the lungs. This provision is more than a physiological accident. It is useful and necessary. It makes of breathing a continuous process instead of an intermittent one, and so provides a constant supply of oxygen. The nerve center which controls respiration depends for its stimulation on carbon dioxide dissolved in the blood. If the carbon dioxide falls too low, stimulation stops until the proper concentration of carbon dioxide is reaccumulated in the blood; then stimulation takes place and respiration is restored. This concentration of carbon dioxide in the blood is reached when the amount of carbon dioxide in the alveolar air is about 5 per cent. By reason of the nice adjustment of the reflexes controlling the depth of breathing, the concentration of carbon dioxide in the lungs is thus kept at its normal uniform level regardless of whether we breathe much or little expired air. "The balance is maintained automatically and without our consciousness, and the limits of this automatic regulation of the volume of air inspired goes far beyond the limit of the necessity for change placed upon it by any respiratory contamination that is ever likely to be found in the air of even the most crowded rooms."

BAD AIR

As the ground beneath these old chemical theories relating to vitiated air was softening and showing signs of giving way, the time-honored prejudice against odors was brought out and used to shore up the crumbling structure. Odors have in many instances profound psychological effects, of which fear is one. The Chinese sought to win battles by carrying forward enor-

mous censers producing foul odors. "Sewer gas" has been notoriously dangerous. The emanations from swamps have been credited with producing all the ills that have been preceded by the adjective "malarial"—from the Latin, *bad air*. The sure prophylaxis against malaria itself consisted in keeping the windows closed at night. From the point of view of general health some night hours acquired especially bad reputations. Thus Hamlet says:

> " 'Tis now the very witching time of night;
> When graveyards yawn, and *hell itself breathes out*
> *Contagion* to this world."

It is a fact of observation that odors usually are noticeable in a closed room when the carbon dioxide content of the air has risen to nearly twice its normal value, that is, to 0.006 per cent.

But science is practical, not sentimental.

The moisture in the vitiated air of rooms when condensed contains notable amounts of the organic impurities previously in the air of the room. This condensed moisture has been injected into normal experimental animals, and even into sensitized animals where the remarkable phenomena of anaphylaxis would enormously aggravate the effect of any protein poison if present—without poisonous effects. It has been thirty-five years since it was first clearly pointed out that if one is strictly cleanly in clothing and person, no odorous substances are given off. And we still self-righteously condemn the ventilation, when we find ourselves in a room of ill-smelling vitiated air.

"The proper study of mankind is Man." The direct study of men in enclosed air-spaces, such as air-tight rooms, has given the correct explanation of his discomfort in rebreathed air. Men have been enclosed in air-tight cabinets until the effects of rebreathed air have become unmistakably evident. Men *outside* the cabinet have then begun and continued to breath through tubes the air from within the cabinet—entirely without discomfort and without discoverable ill effects. Then, men within the cabinet have begun and continued to breathe through tubes, fresh air from the outside—entirely without discoverable amelioration of their discomfort and distress. Obviously the ill effects of bad air are not due to the air inside of the lungs, but are due to the air that is outside of the body. Further experiments show an immediate restoration of the confined men to comfort and normality, by modifying the enclosed air of the cabinet in any one of the three following ways: (1) by cooling it, (2) by drying it,

(3) by moving it. So that now, well on in the 20th century, we are coming to use intelligently, in room temperature and ventilation the means given us by discovery in mediæval times; I refer to the thermometer, the hygrometer and the anæmometer.

Let us now take a less anthropomorphic view of the animal, man, in his relations to heat and moisture and wind, in order to formulate his problem more clearly. To begin with, the Egyptian mummy is a very dry fellow because he has lost the 58.5 to 65.0 per cent. of water that was in life a part of him. Man is a moist, living mass of colloidal solutions, emulsions and jellies, supported on a small amount of mineral matter. He may be looked upon as similar to a living sponge that in the past withdrew from his native element, the sea, and has since lived immersed and at the bottom of an ocean of more or less moist and more or less quiet air. This moist, spongy organism is constantly losing water by evaporation and by flow; if irremediable drying out is to be prevented water must be constantly poured into it. Any agency that disturbs the balance that ages of habit have established with respect to gain and loss of water, is potentially destructive to this organism, and it therefore reacts to such disturbances. For example, it is stated, "In such a place as Death Valley in summer, with the thermometer at 100° to 135° in the shade, it is almost impossible to drink enough water to preserve normal physiological conditions. . . . People who stay through the summer are in danger of suffering permanent injury to health." The problem of water balance in this organism is accompanied inseparably by a similar problem of heat balance. This organism is constantly losing heat, and must constantly have heat put into it if irremediable damage is to be avoided. Any agency that disturbs the balance that ages of habit has established with respect to gain and loss of heat is potentially destructive to this organism, and it therefore reacts to such disturbances. From the highest air temperatures man experiences in some of the industries, to the lowest met in polar explorations, is about 325°, but if the changes are not too sudden and unexpected, man is usually able to contrive a way to survive. Studies of artificial hibernation produced at will in certain other warm-blooded animals have led to the conclusion that "all the arrangements in the animal economy for the production and loss of heat are themselves fully regulated by the central nervous system, there being a thermogenic center—situated above the spinal cord, and according to some observers, in the optic thalamus." The source of his heat, as of the rest of his energy, is his

food, and on a 3000 calorie diet man turns out, as heat alone, somewhere around enough energy to raise five and a half million pounds one foot vertically against gravity, or in the more usual heat units, about 7000 British thermal units (B.T.U.'s) in twenty-four hours. Assuming that his body will heat up in just the same ratio as water, unless a 150-pound man is relieved of this heat he will develop within an hour a fever reading about 100.4° F. and in about four hours his temperature would reach 106.° As a man sometimes succeeds in continuing his existence upward of 600,000 hours, that is, for "three score years and ten," he must have ready means of losing heat.

Man loses about 50 per cent. of the water and 3 per cent. of the heat in the urine and fæces; about 10 per cent. of the water and 20 per cent. of the heat by respiration through the lungs; and about 40 per cent. of the water and 77 per cent. of the heat through the skin. It is evident then that in heat loss the skin is a far more important organ than are the lungs and that in water loss it ranks in importance with the kidneys. It is therefore to be expected that the air outside the body is of more importance than the air inside the lungs, because the air outside the body is the receptacle for all of the water and most of the heat lost through the skin.

The main methods of heat loss through the skin are by convection, radiation and evaporation. The heat loss through the lungs is by evaporation. The heat loss by convection decreases as the temperature of the air increases, falling from an estimated 425 B.T.U. per hour at 56° F. (with 56 per cent. humidity) to zero B.T.U. per hour when the air is at blood heat (with 56 per cent. humidity). On the other hand, the heat loss by evaporation increases with increasing air temperature, rising from an estimated value of 50 B.T.U. per hour at 56° F. (with 56 per cent. humidity) to 400 B.T.U. per hour when the air is at blood heat (with 56 per cent. humidity). The heat losses by radiation are but slightly known, but are held to decrease with rise of air temperature.

At elevated air temperatures, therefore, it is absolutely necessary for man to be able to evaporate water rapidly from his body into the air. But the capacity of the air at any temperature, for water, depends upon how much water it can still take up at that temperature before it becomes saturated with water. The less water there is already in the air at any temperature, the more water it can take up (at that temperature) and therefore the more heat it can relieve man of *via* evaporation from this body. The more water there is already

in the air at any temperature, the less it can take up (at that temperature) and therefore the less is it suited to relieve man of heat by evaporation. If now the temperature of the air is high, since heat loss by convection and radiation has thereby been diminished, it is evident that if the warm air is also moist, the heat loss by evaporation is also diminished—and the discomfort that is the prodrome of heat-stroke appears. Reflex actions through the thermogenic center in the central nervous system now stimulate the flow of blood to the skin, thereby causing an elevation of temperature at its surface and thus facilitating the loss of heat by convection and radiation—to compensate for the reduced loss by evaporation. For example, in the case of weaving mill workers who operate amid the steam blown into the sheds, and whose bodies and clothing are consequently moist, the skin of the face has been found to be 4° to 13° F. higher in the mill (wet bulb 71° F.) than when at home (wet bulb 55° F.).

Where it is impossible to moderate the temperature or reduce the moisture in the air, a satisfactory remedy is the third one mentioned in the cabinet experiments—namely, to move the air. This does not mean to empty the closed space and fill it with fresh air; it means, to set the air within the closed space in motion. In the cabinet experiments, for example, the surface skin temperature of a man rose 4.3° F. in 13 minutes, due to elevated temperature and moisture-content in the air; but dropped 4.5° F. immediately after a fan, under which he was standing, was started. "At 80° F., with moderate humidity, or 70° to 75° F., with high humidity, almost all persons begin to show depression, headache, dizziness and a tendency to nausea. . . . The subjective symptoms appear when the surface skin temperature reaches a certain height, for example, 93° to 95° F. on the forehead (89.5° to 91.5° in cases of heart disease) and when the relative moisture of the layer of air in contact with the skin increases 20 per cent. to 30 per cent." In all instances where relief was produced by setting the air in motion by the fan, discomfort returned promptly when the fan was stopped. This cycle could apparently be repeated any number of times.

The last step logically in the progress of our knowledge of temperature and ventilation, would seem to be to establish standards. Any such project is full of difficulties because of the great variations shown naturally by the human animal and because of his marked ability to develop tolerances and to acclimate himself. The same difficulties, however, beset the use of medicines; yet you all agree

upon certain dosages of each medicine to be used in advance of knowledge of the variations shown by the particular patient or his tolerances. An interesting and important contribution in this matter, which embodies years of experimenting, is at hand, and I shall speak of it in closing.

The experiments reduce themselves to placing persons in a room, the atmosphere of which may be altered at will, and at suitable times inquiring as to their comfort or discomfort. The room equipment permits of any velocity of movement up to 2800 feet per second, any temperature from 28° to 94°, and any relative humidity from 18 per cent. to 100 per cent. The results of these experiments, combined with earlier experiments in school rooms where the number of subjects was larger but the number of possible variations smaller, have been combined into a graphic chart—Figure I. It is a study of "Degrees of Discomfort" of the average person (in Chicago).

Any movement of the air increases the rate of evaporation from the skin, and moves air heated by convection from the skin away from the skin, thus bringing cooler air (at all temperatures below skin temperature) to the skin. The investigation has shown that under

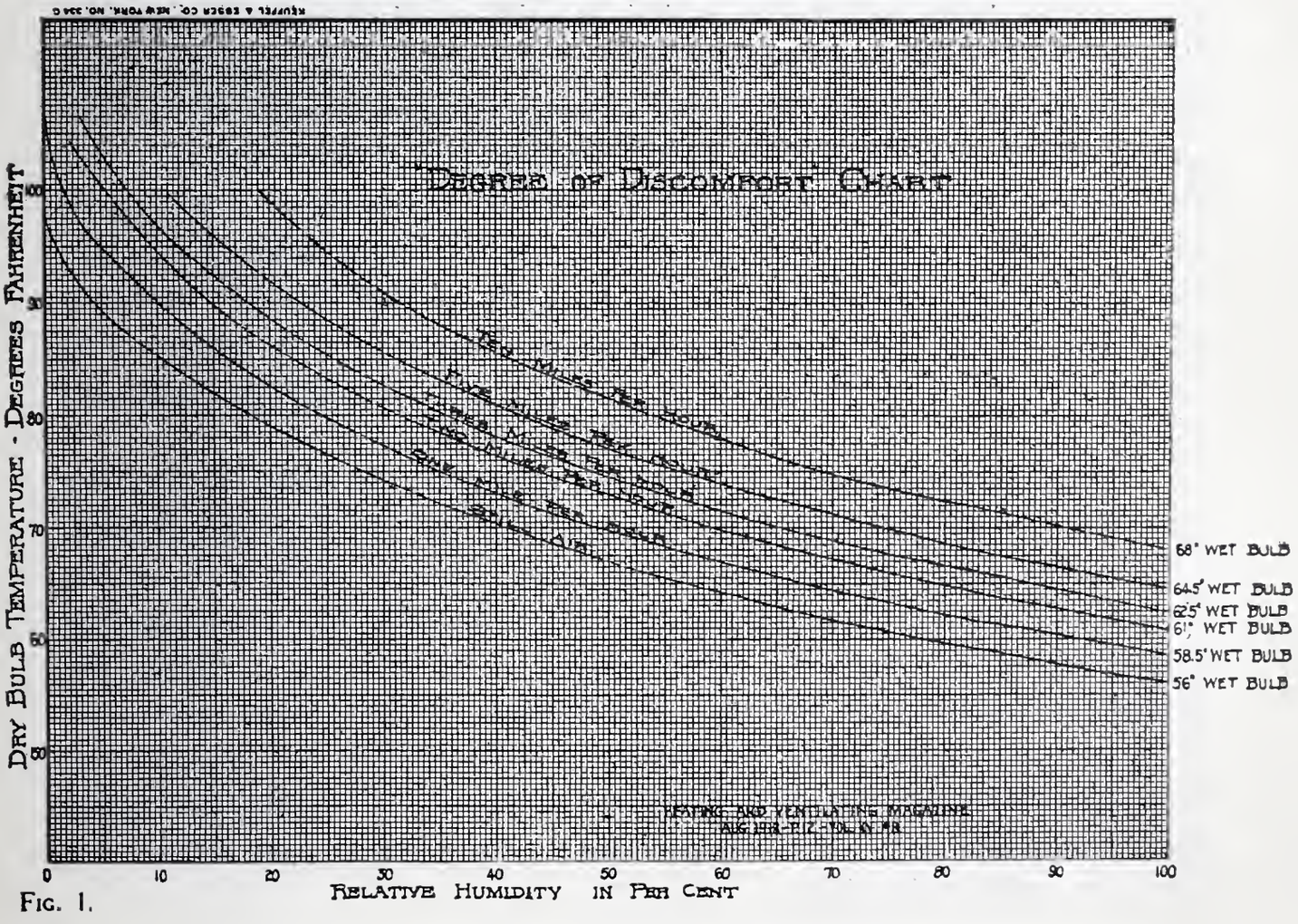

Fig. 1.

certain velocities of air movement, at a given temperature, the average person will be most comfortable when the wet bulb shows an average reading, as follows:

Velocity of Air, in Miles Per Hour	*Wet Bulb Reading*
0	56.0
1	58.5
2	61.0
3	62.5
4	63.5
5	64.5
6	65.5
7	66.0
8	66.5
9	67.0
10	68.0

Since the relative humidity is gotten from the wet bulb reading at any (dry bulb) temperature, it is possible to determine from these figures for any temperature and rate of air motion just what the average humidity for comfort of the average person should be. In the graph, the thermometer (dry bulb) readings are plotted vertically and the relative humidity percentages are plotted hoizontally. Each curve gives the temperatures and relative humidities that combined produce the comfortable wet-bulb reading, at each of the several velocities of air movement stated on the diagram at the end of each curve. The curves for still air and for air at 1, 2, 3, 5 and 10 miles per hour are given.

Thus, to apply these curves to an example: In order to find the approximate temperature for comfort, with 90° F. and 60 per cent. relative humidity, follow the 60 per cent. line up until it intersects the still air line and then read at the left of the table the corresponding temperature for comfort. This proves to be only 65°. Since the actual air temperature was 90°, the degrees of discomfort equal 25°. If, however, a two-mile breeze had been blowing, then 70° would have been the comfortable temperature, or the degrees of discomfort would have been only 15°. This shows how a gentle breeze may render the hot day more endurable.

It remains to speak briefly of the experimental determinations. The velocity of the wind outdoors is best taken from the weather bureau records. Indoors a sensitive anæmometer, properly calibrated, is used if the air is not still. An easy way to calibrate it is by the aid of the automobile and speedometer, on a calm day.

The relative humidity may be determined quite accurately with the sling psychrometer, and accurately enough, perhaps, for most purposes by the ordinary wet and dry bulb thermometer outfit, *provided* an electric fan is set to drive the air of the room across the bulbs of the thermometers at a rate not less than 15 feet per second,—which is about 10.2 miles per hour.

The experimental results embodied in this graph will enable one to explain his discomfort under any ordinary conditions, if his discomfort be due to the atmospheric conditions. It will also enable him to arrive at a more or less quantitative expression for his discomfort. But it should be added for the benefit of those seeking greater precision throughout a wider range of conditions, that more exact and extensive studies have been made and that the results are available in the literature upon industrial hygiene.

Schedule of

POPULAR SCIENCE LECTURES

for 1931

"What is Gas?"

Wednesday January 14 ..... Prof. F. P. Stroup

"Radioactivity."

Wednesday, January 21 ..... Prof. Geo. Rosengarten

"Over the Roof of North America."

Wednesday, January 28 ..... Mr. Lester W. Strock

"Ice Cream."

Wednesday, February 4 ..... Prof. D. W. Horn

"Fungous Friends and Foes."

Wednesday, February 11 ..... Prof. M. S. Dunn

"Under the Lime Tree."

Wednesday, February 18 ..... Prof. Geo. W. Perkins

"Liquid Death."

Wednesday, February 25 ..... Prof. Paul Q. Card

"How We See."

Wednesday, March 4 ..... Prof. H. C. Wood

"Concentrated Sunshine."

Wednesday, March 11 ..... Prof. E. Fullerton Cook

"Food Poisoning and Poisonous Foods."

Wednesday, March 18 ..... Prof. Chas. H. LaWall

"What Fur?"

Wednesday, March 25 ..... Prof. Ivor Griffith

"Hum and Bug."

Wednesday, April 1 ..... Prof. Adley B. Nichols

"Silicon."

Wednesday, April 8 ..... Prof. Arno Viehoever

"The Story of Alcohol."

Wednesday, April 15 ..... Prof. C. C. Pines

"Milk—Cows' and Mothers'."

Wednesday, April 22 ..... Prof. Louis Gershenfeld

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